CDF confronting the SM BY ALL POSSIBLE MEANS

or the keys to open the door of the BSM world

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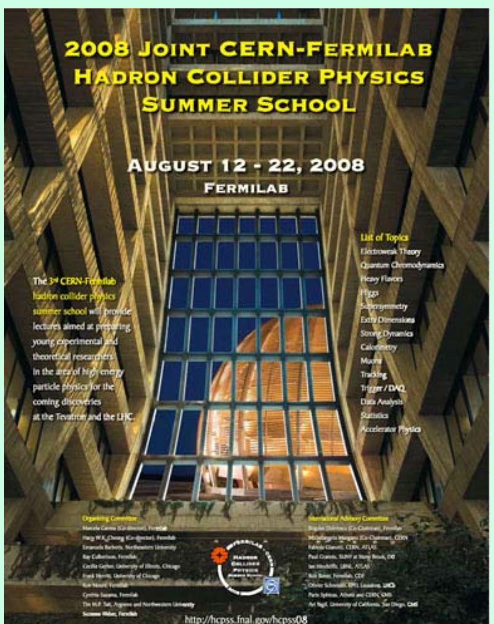
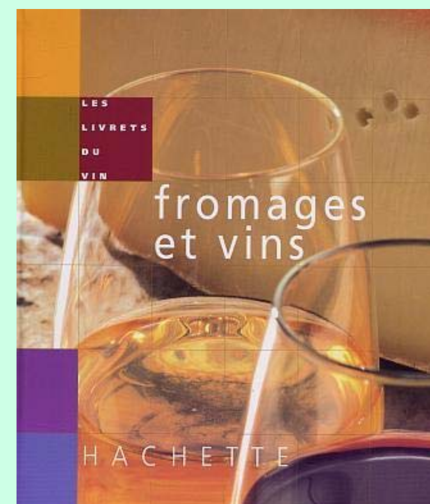


HADRON COLLIDER PHYSICS
Summer school 2008
FNAL WINE & CHEESE seminar
FERMILAB, August 15, 2008



Let's try some of these BSM Keys(*):

This talk tries to give just some ideas on the capabilities and present achievements of CDF experiment to confront the BSM, which is the main goal ahead of us.

- **HEAVY FLAVOUR**:

  How precision measurements may lead to BSM, the Bs sector & some flavour of rare B decays
- **EWK**: W mass, double & forbidden boson couplings
- **TOP**: mass and some non standard top properties.
- **HIGGS sector:** the many ways to look for a light Higgs
- ***Breaking the waves***:

  Some BSM "typical" signatures: multijets and multileptons.

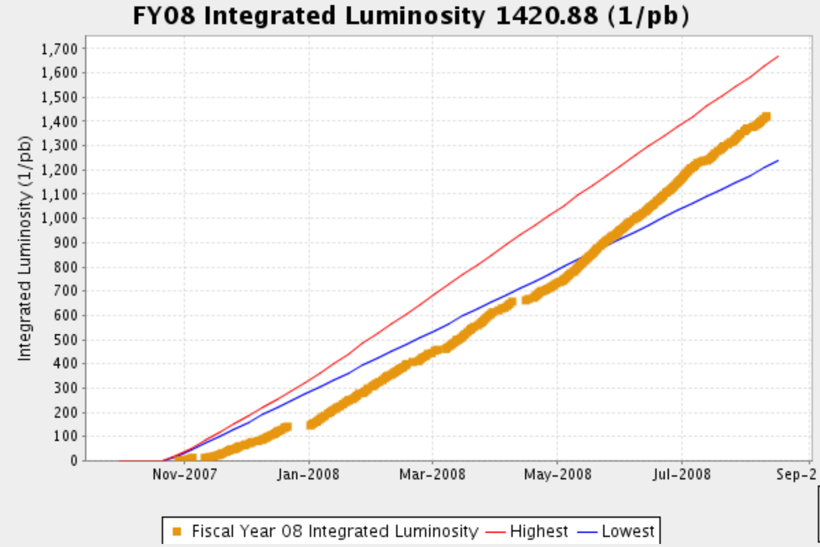
But first of all **THE KEY**-ISSUE= **to build the needed detector**

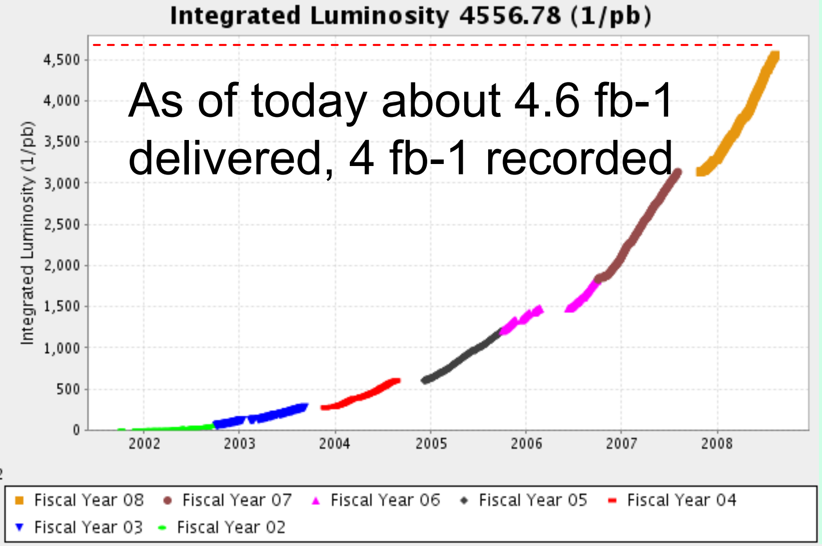
$\Rightarrow$ the main assets of the ***constantly rejuvenated*** CDF detector

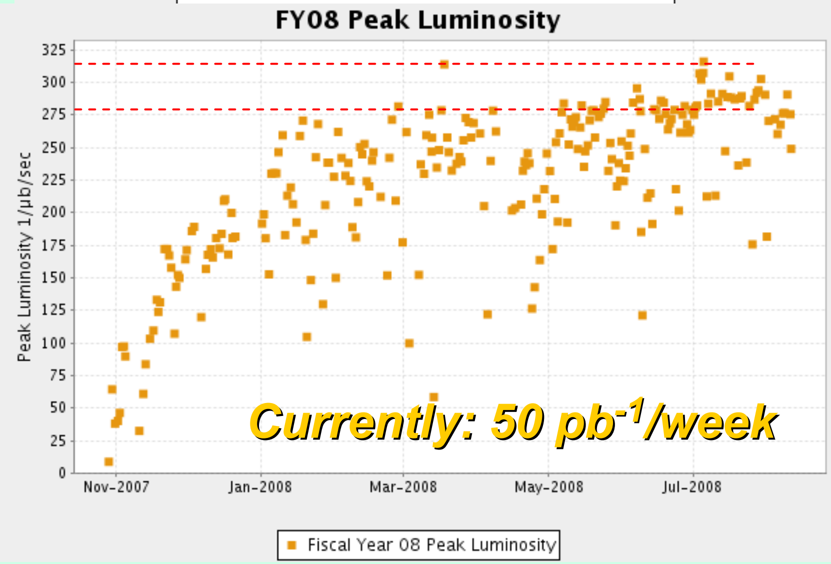
http://www-cdf.fnal.gov/physics/S08CDFResults.html

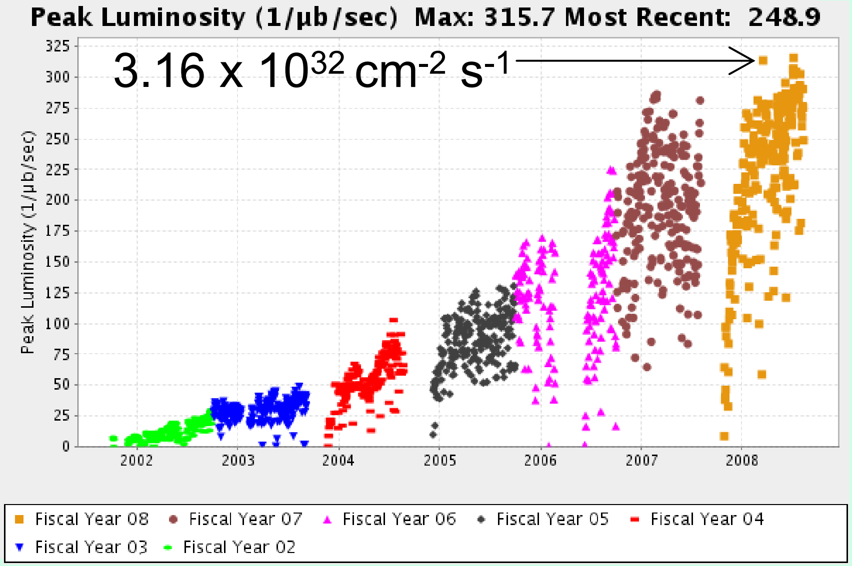
Tevatron is breaking records

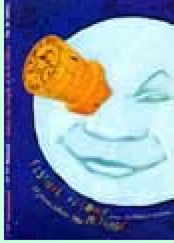
(and it better does: LHC first collisions Sept 10th)





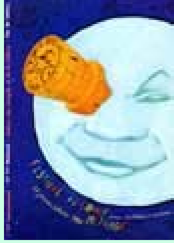


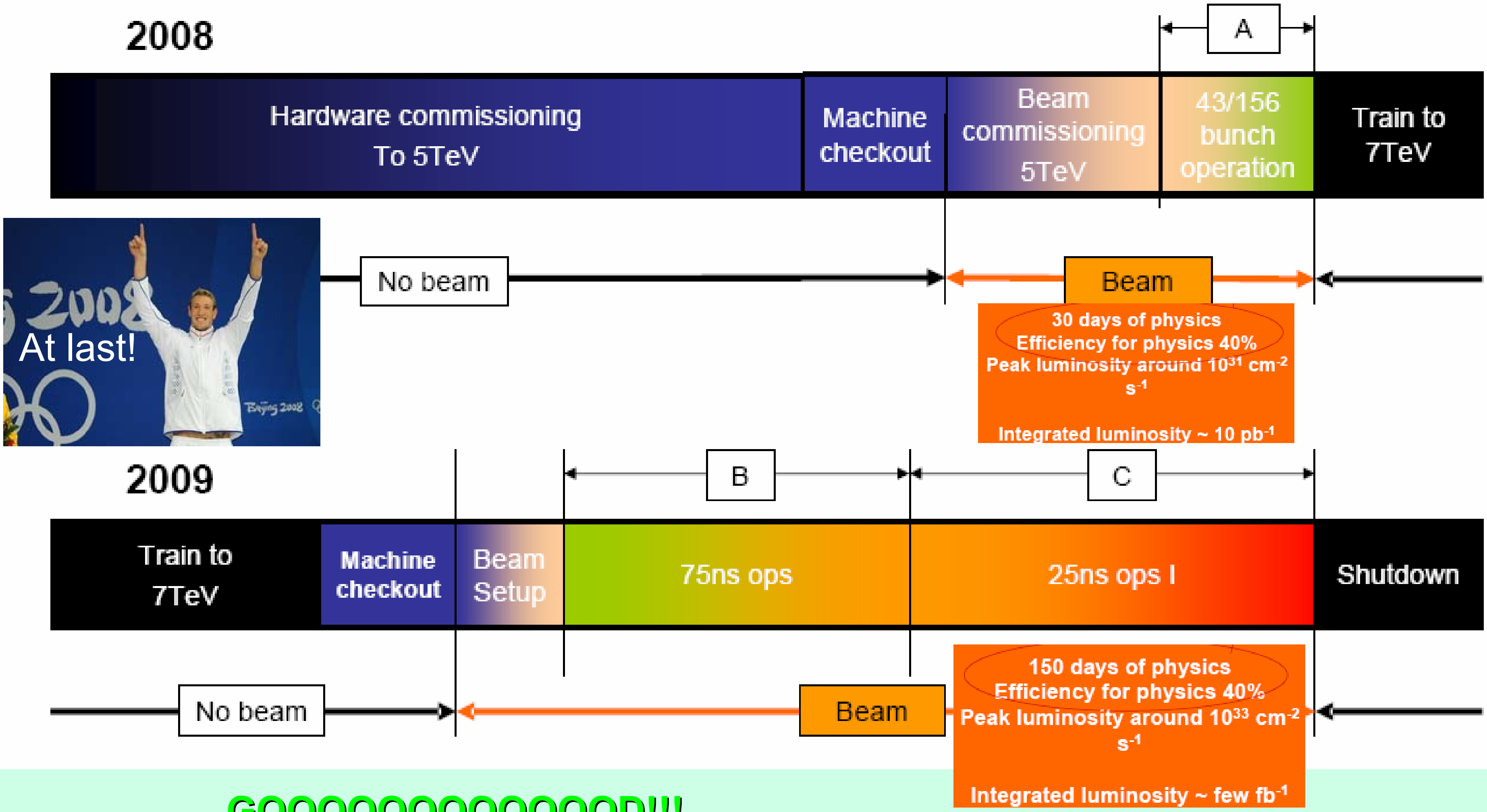




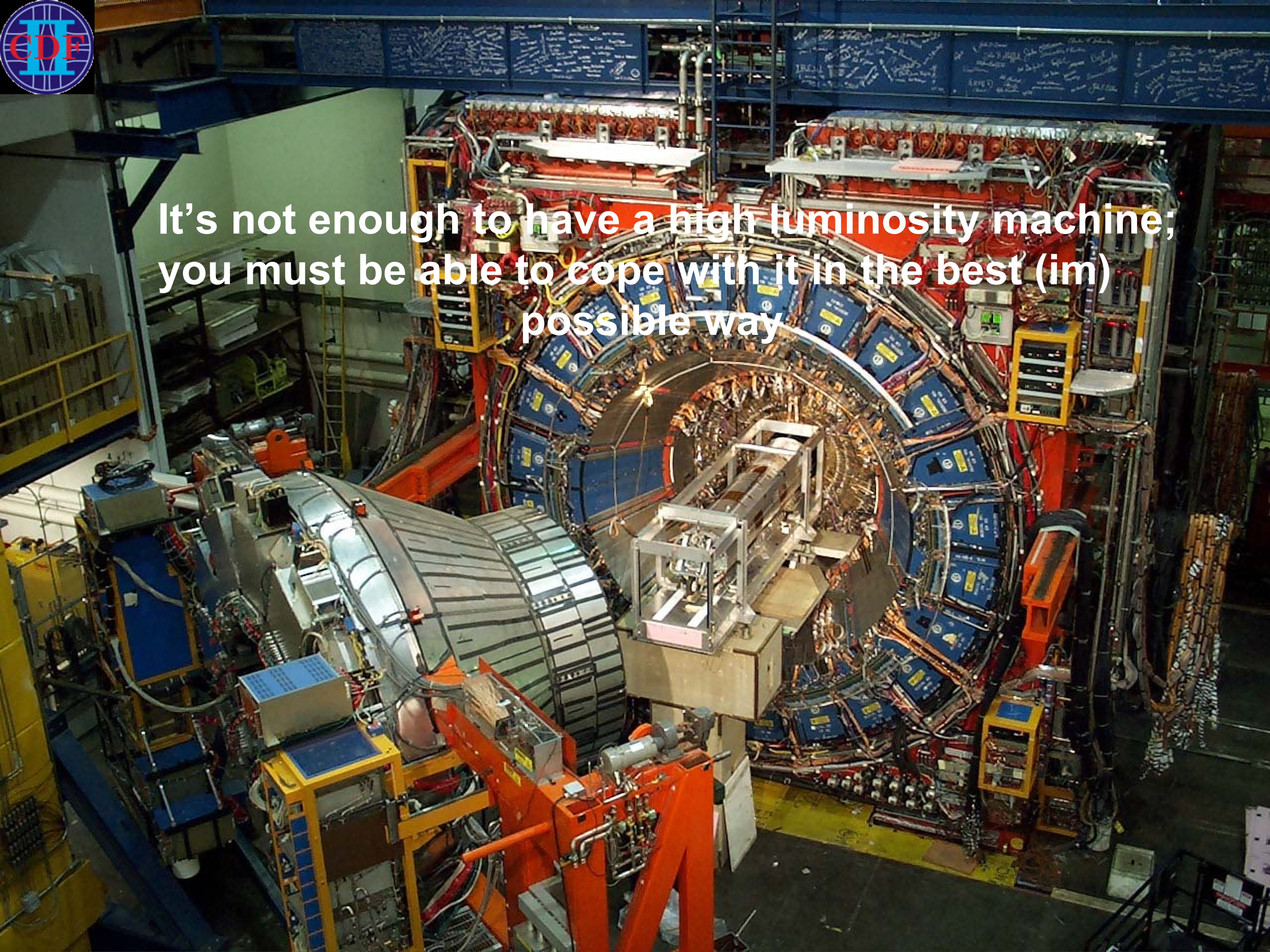
Competition coming…

Courtesy Lyn Evans



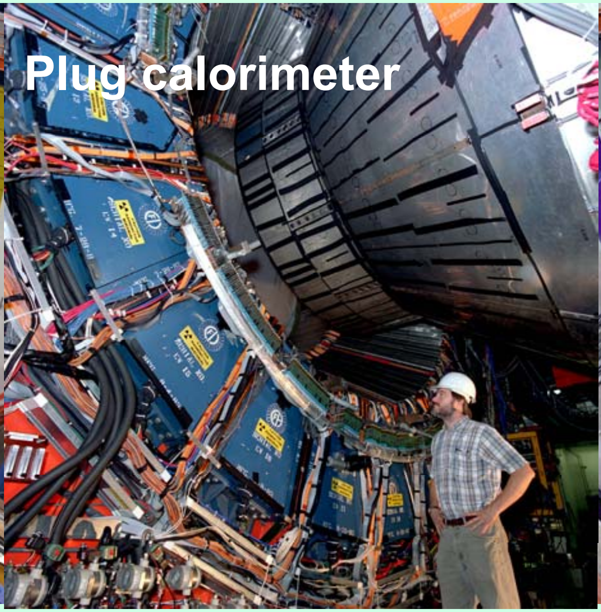


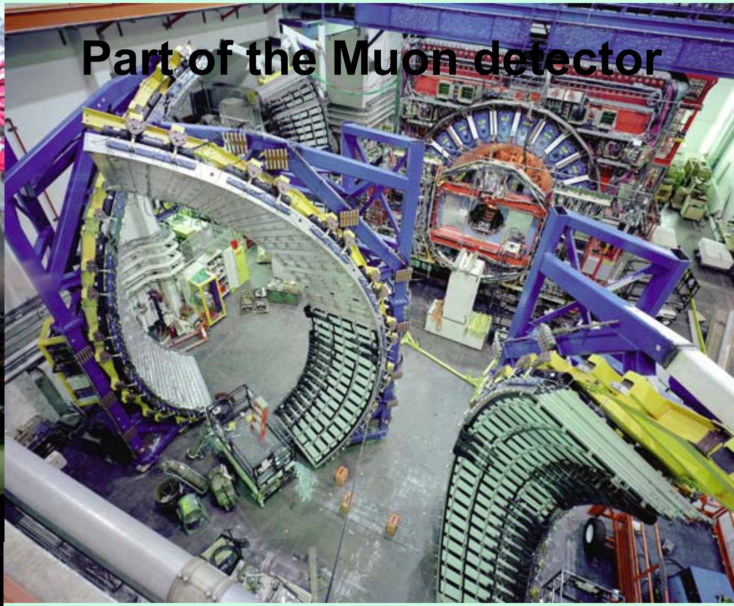
GOOOOOOOOOOOOD!!!



It’s not enough to have a high luminosity machine; you must be able to cope with it in the best (im) possible way

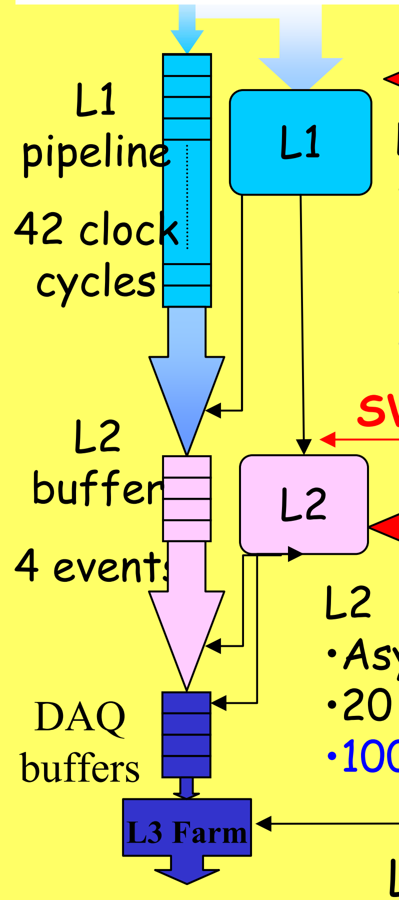
Since over about 3 decades (!!), several generations of experimentalists have been working on building and continuously upgrading CDF with innovative and pioneering ideas making it to be still today at the forefront and able to make discoveries** (top, Bs mixing and more still to come)* ***plus important breakthroughs both in Physics and Detector techniques.





Very important contribution of Tracker in CDF Trigger Architecture

7.6 MHz Crossing rate



XFT here

L1
- 7.6 MHz Synchromous Pipeline
- 5.5 μs Latency
- 30 kHz accept rate

SVX read out after L1

SVT here

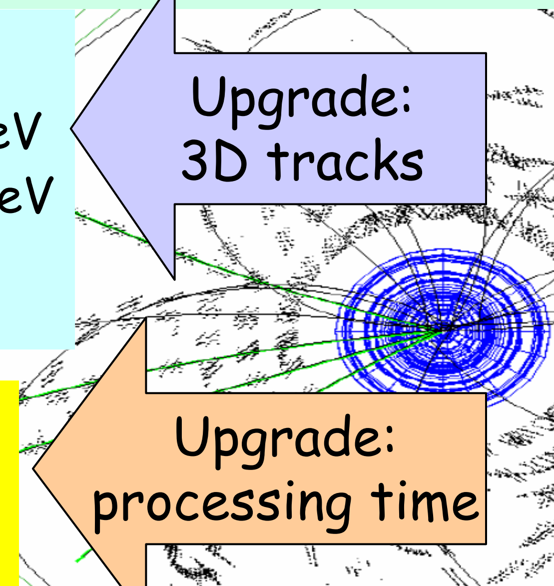
L2
- Asynchromous 2 Stage Pipeline
- 20 μs Latency
- 1000 Hz accept rate

L3: CPU farm Full event Reconstruction Speed-optimized offline code

Mass Storage (~100 Hz)

XFT – Level 1

all trck pT>1.5 GeV
σ(1/pT) = 1.7%/GeV
σ(φ0) = 5 mrad
96% efficiency



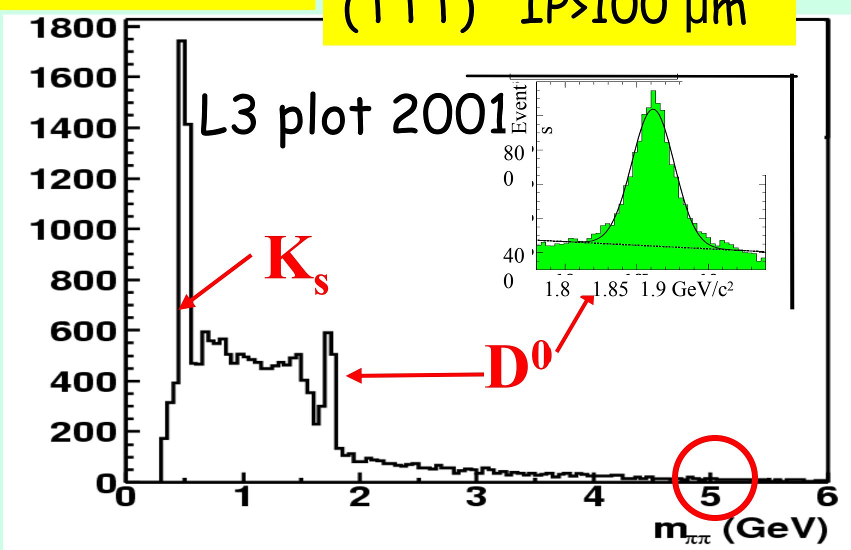
Upgrade: 3D tracks

SVT – Level 2

all trck pT>2 GeV
σ(IP) = 35 μm,
σ(1/Pt) = 0.3 %
σ (φ0)=1 mrad

Upgrade: processing time

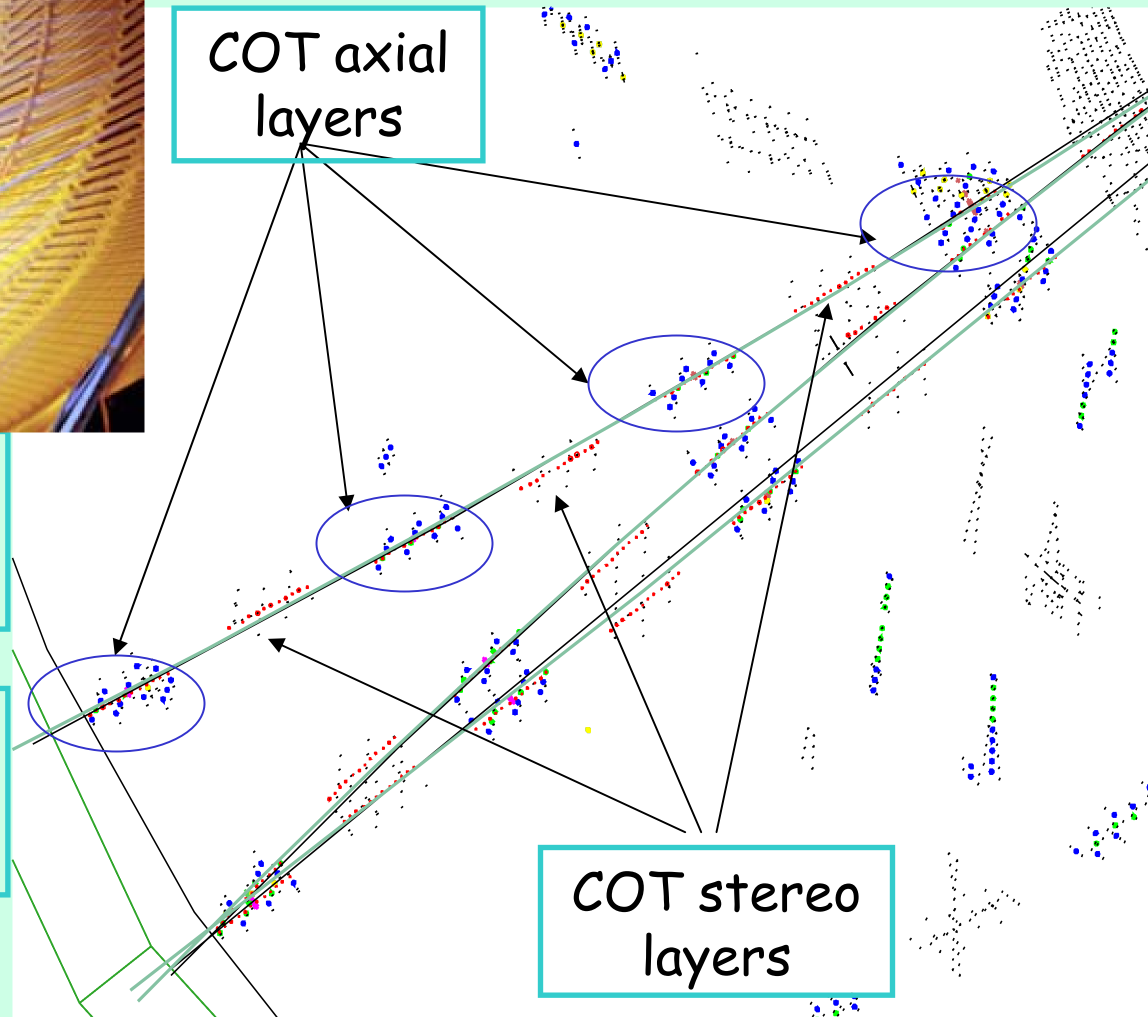
Two Track Trigger (TTT) IP>100 μm



e, Aug1

Gaseous tracking chamber rebuilt from run I to run II to cope with luminosity x100 and for the first time a tracking LV1 trigger:

eXtremelyFastTracker

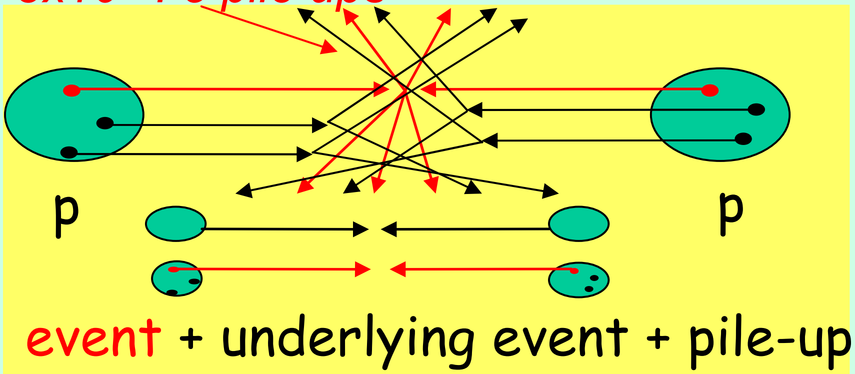


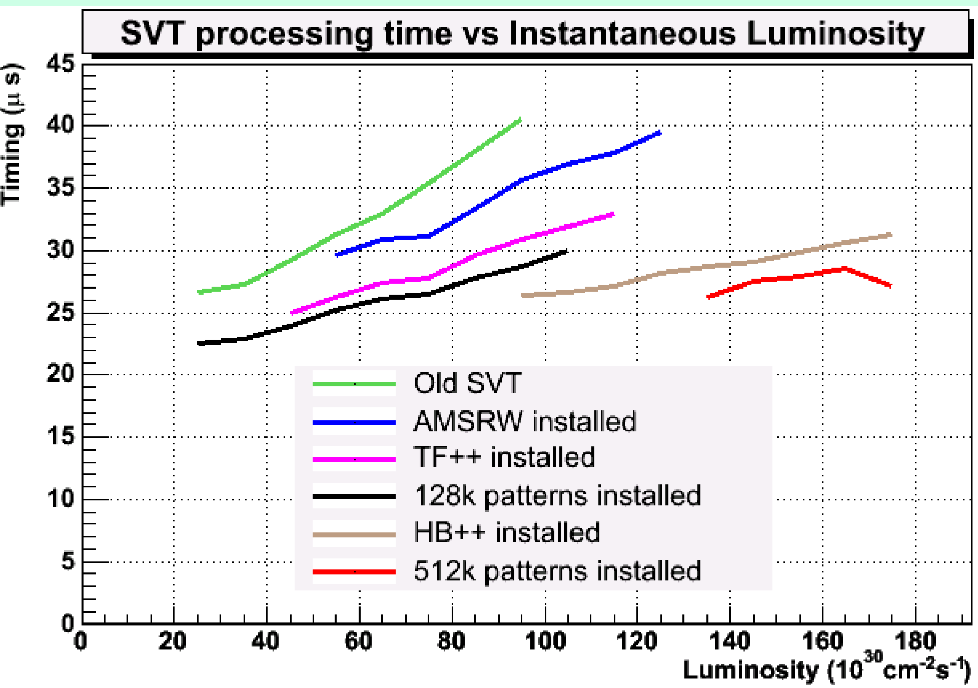
Good hit patterns are identified as segments, then segments are linked as tracks

XFT 3D upgrade:
Add info from stereo layers
Fake rejection ~8

Upgrade SVT for luminosity

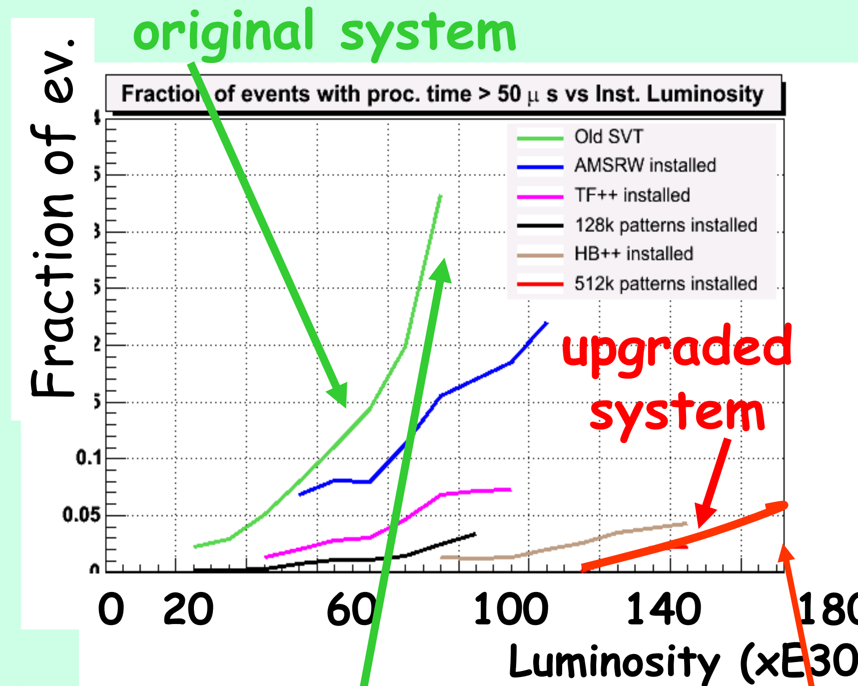
At $3x10^{32}$: 5 pile ups





Upgrade: Faster SVT components and:

32Kpatterns → 512Kpatterns new AM.



Original SVT
turned off above 90xE30

Upgraded SVT can run @high Lumi

Good Data@ higher Luminosity
More Data @ lower Luminosity

- **HEAVY FLAVOUR WORLD**

  Heavy flavours as probes for New Physics

  Bs Mixing and CP violation

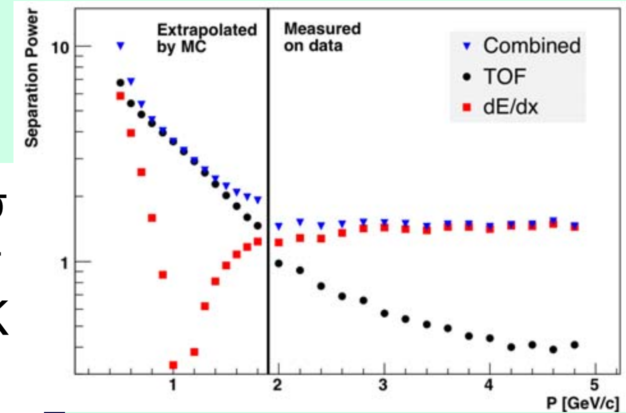
  and a zest of

  some rare B decays…

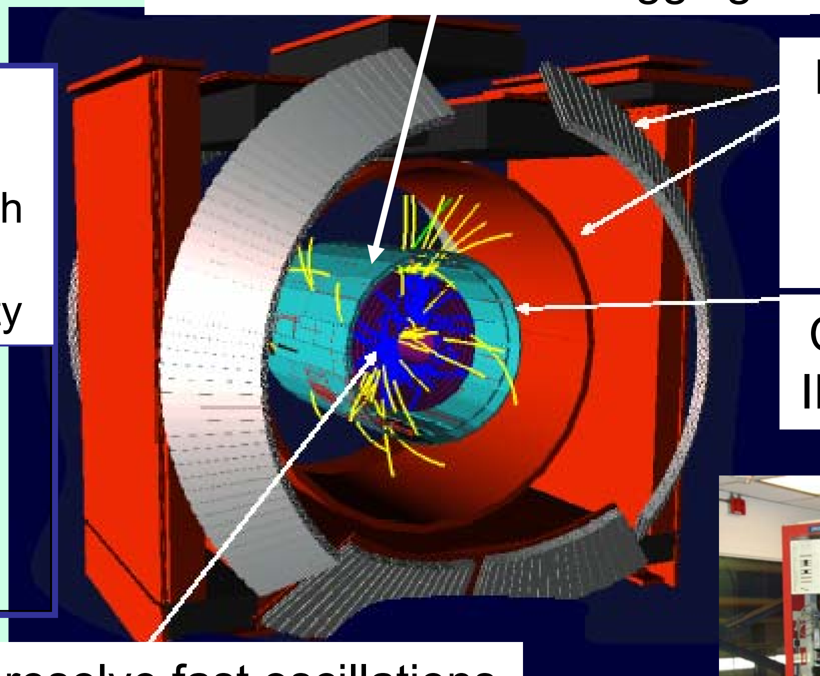
HFP: CDF assets

CRUCIAL: TRIGGER & PID

dE/dx in drift chamber (1.5σ @p>2 GeV/c) and TOF (2σ @p<1.6 GeV/c) provide π/K ID crucial in flavor tagging



Vertex position known with ~25 μm uncertainty



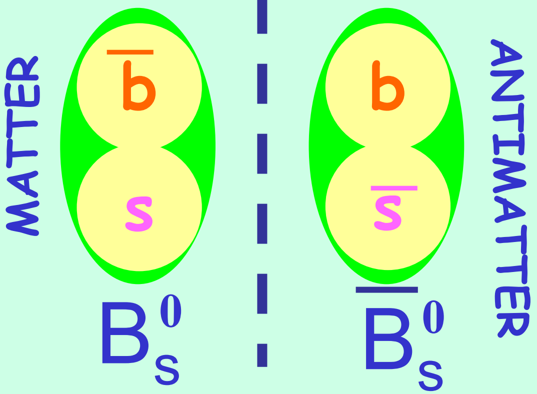
High muon acceptance (84% azimuthal at |eta|<1.5) and precise muon ID

Calorimeter for electron ID used in flavor tagging

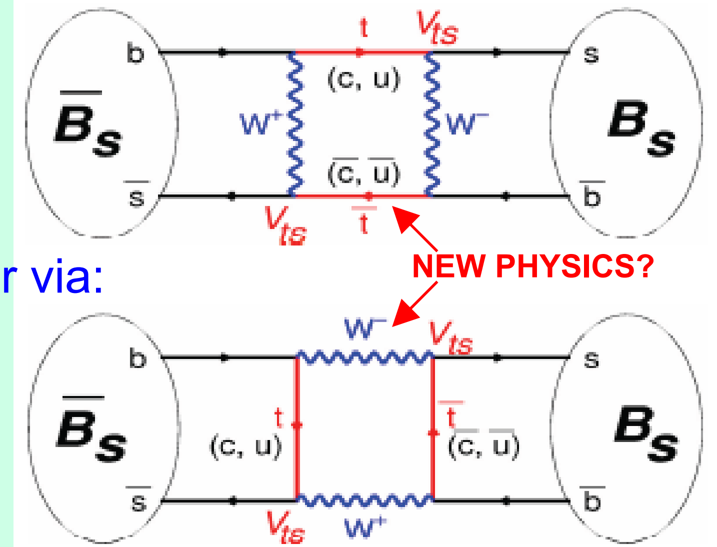
Excellent vertexing to resolve fast oscillations (silicon detector) and momentum resolution for improving S/B (large radius drift chamber) immersed in 1.4 T B field.

Welcome to the B_s-world:

Bs mesons = {bs} bound states



Transitions Matter ↔Antimatter via:



- Simplified Schroedinger equation describing mixing and decay

$$i\frac{d}{dt}\begin{pmatrix} B_q^0(t) \\ \overline{B_q^0}(t) \end{pmatrix} = (M - \frac{i}{2}\Gamma)\begin{pmatrix} B_q^0 \\ \overline{B_q^0} \end{pmatrix} \qquad \begin{pmatrix} M_{11} & M_{12} \\ M_{12}^* & M_{22} \end{pmatrix};\begin{pmatrix} \Gamma_{11} & \Gamma_{12} \\ \Gamma_{12}^* & \Gamma_{22} \end{pmatrix}$$

- The mass and lifetime eigenstates (with $G_{12}/M_{12} << 1$)

$$|B_L>= p|B_q^0> +q|\overline{B}_q^0> \qquad \Delta m_q = m_H - m_L = 2|M_{12}^q|$$

$$|B_H>= p|B_q^0> -q|\overline{B}_q^0> \qquad \Delta\Gamma_q = \Gamma_L - \Gamma_H \cong -2|\Gamma_{12}^q|\,\mathrm{Re}(\frac{\Gamma_{12}^q}{M_{12}^q}) = 2|\Gamma_{12}^q|\cos(\varphi_s)$$

System defined by
5 parameters:
Masses: m_H, m_L
Lifetimes: Γ_H, Γ_L
($\Gamma = 1/\tau$),
Phase: Φ_s

Bs observables: $\Delta m_s = m_H - m_L \approx 2|M_{12}|$ defines mixing oscillation frequency
Different Lifetimes: $\Delta\Gamma_s = \Gamma_L - \Gamma_H \approx 2\,|\Gamma_{12}|\,\cos\,\Phi_s$
CPviolating phase: $\Phi_s^{SM} = \arg(-M_{12}/\,\Gamma_{12}) \approx 0.24^0$:***small value predicted by SM***

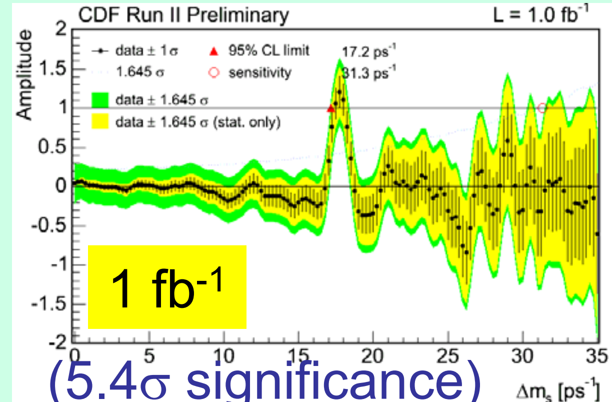
Δm_s measurement

PRL. 97, 242003 (2006)

Δm_s = 17.77±0.10(stat)±0.07(syst) ps^{-1}

Extracted parameters dominated by theoretical errors; Need more from LQCD

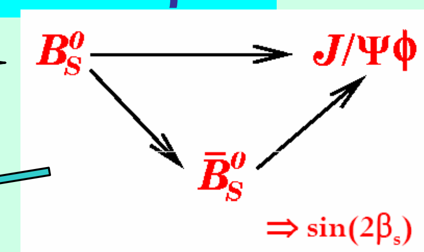
$|V_{ts} / V_{td}|$= 0.2060 ± 0.0007 (exp) $^{+0.0081}_{-0.0060}$ (theo)

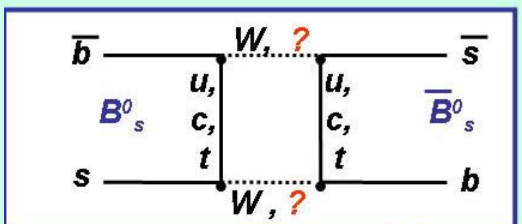


(5.4σ significance)

CDF present focus $\Delta\Gamma_S=\Gamma_H-\Gamma_L$, $\Gamma=(\Gamma_H+\Gamma_L)/2$ and βs

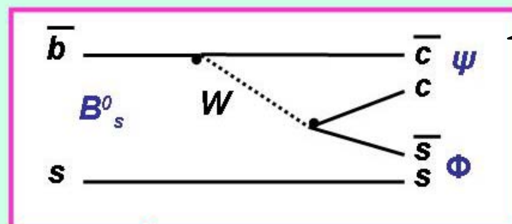
ALL in ONE process





Mixing phase – sensitive to NP

+



Tree $b\to \bar{c}cs$ phase ≈ 0

βs = phase of *b→ccs* transition accounts for decay & mixing+decay= 2.2^0(SM prediction)

If NP occurs in mixing: $\Phi_s = \Phi_s^{SM} + \Phi_s^{NP}$ and $2\beta_s = 2\beta_s^{SM} - \Phi_s^{NP}$

➔ standard approximation: $\Phi_s = -2\beta_s$

β_S measurement in $B_s \rightarrow J/\Psi\Phi$: analyse overview

Courtesy Diego Tonelli

$B^0_s \rightarrow J/\psi(\rightarrow \mu^+\mu^-)\Phi(\rightarrow K^+K^-)$

Vertex known at ~25 μm

Sensitivity to phase increases if CP-odd and CP-even final states are treated separately

Combine everything in a

Maximum Likel

$J/\psi\ \Phi$

B^0_s

$\overline{B^0_s}$

$\ell = 0$

$\ell = 1$

$\ell = 2$

$\mu^+\mu^- K^+ K^-$

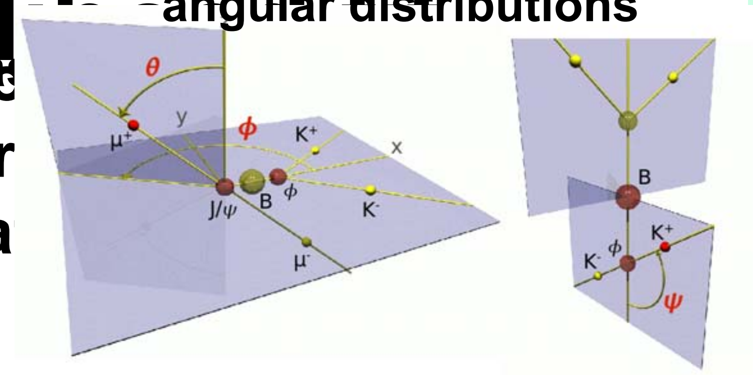
Sensitivity t

Mea

mesons of differ

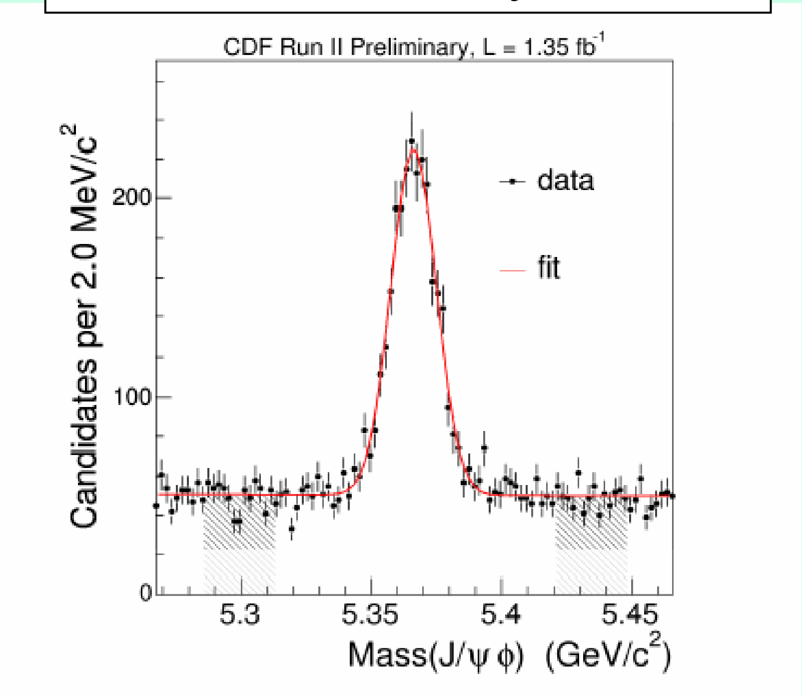
are trea

Infer CP from t-dependent angular distributions



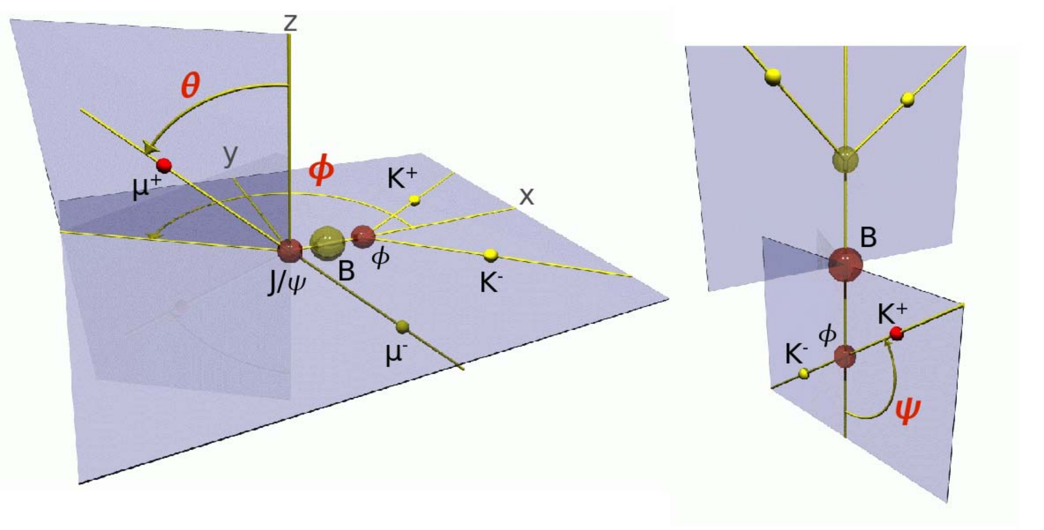
Signal extraction and CP-determination

1.4/fb, ~2000 decays, S/B~2



$B^0_s \rightarrow J/\psi(\rightarrow \mu^+\mu^-)\Phi(\rightarrow K^+K^-)$

NN maximizes $S/\sqrt{(S+B)}$. Trained on MC for signal and mass-sidebands for background.



Determine CP of final state from angular correlations.

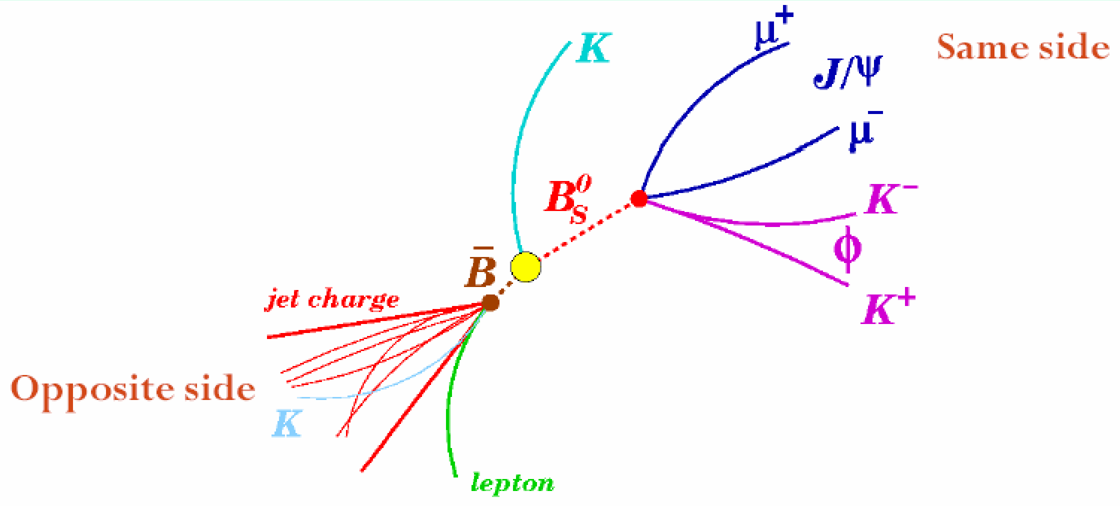
Flavour-tagging performance

Same tagging used successfully for mixing-frequency measurement

Opposite Side: looks at decay of the 'other' *b*-hadron in the event

Same Side: exploits the charge/species correlations with associated particles produced in hadronization of reconstructed B^0_s meson

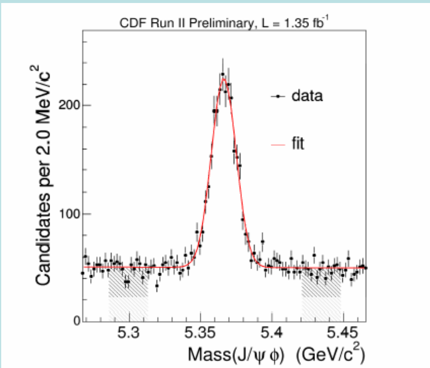
OST efficiency: 96±1%
SST efficiency: 50±1%



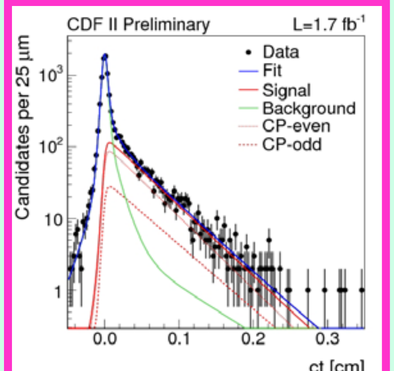
Output: decision (*b*-quark or anti*b*-quark) and the probab. of being correct

Wrapping up all together in a fit

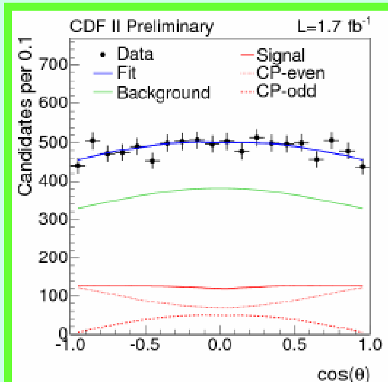
$$f_s P_s(m|\sigma_m) P_s(t, \vec{\rho}, \xi | \mathcal{D}, \sigma_t) P_s(\sigma_t) P_s(\mathcal{D})$$



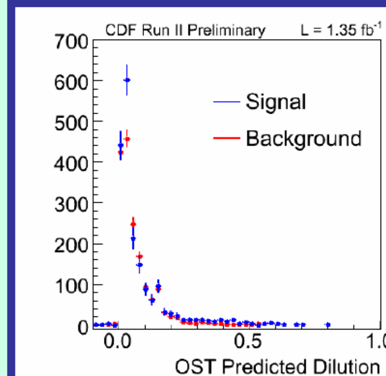
Mass
MC (signal) and sideband data (background)



Decay-time
exponential (signal) empirical model for background



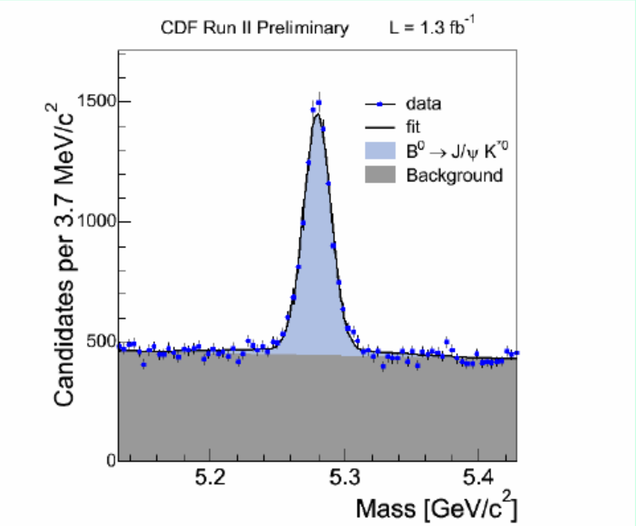
Angles
MC and data (signal), sidebands (background)



Tagging

Data-driven checks (and results!)

Angles



$c\tau = 456 \pm 6\ (\mathrm{stat}) \pm 6\ (\mathrm{syst})\ \mu\mathrm{m}$

$|A_0(0)|^2 = 0.569 \pm 0.009\ (\mathrm{stat}) \pm 0.009\ (\mathrm{syst})$

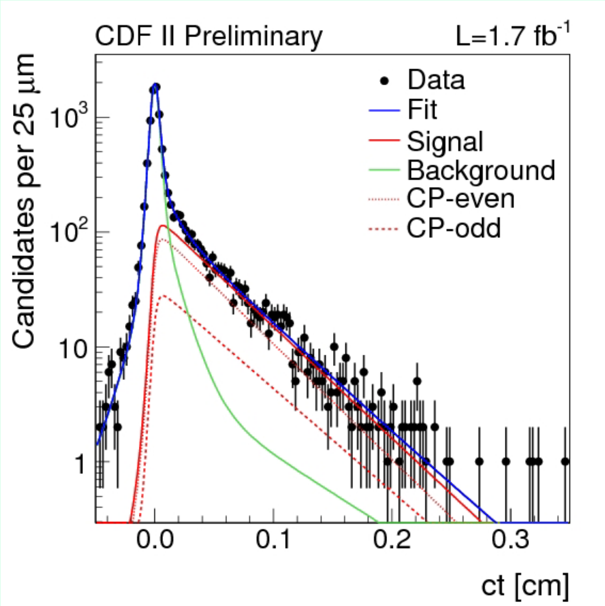
$|A_\parallel(0)|^2 = 0.211 \pm 0.012\ (\mathrm{stat}) \pm 0.006\ (\mathrm{syst})$

$\delta_\parallel = -2.96 \pm 0.08\ (\mathrm{stat}) \pm 0.03\ (\mathrm{syst})$

$\delta_\perp = 2.97 \pm 0.06\ (\mathrm{stat}) \pm 0.01\ (\mathrm{syst})$

Measured polarization of $B^0 \to \psi K^*$: <u>consistent </u>w/ B-factories (and competitive!)

Mass-lifetime



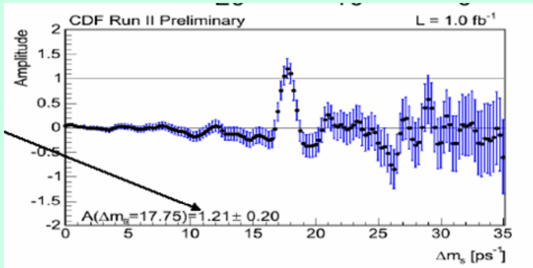
Measurt w/o flavor tagging

$c\tau_s$ = 459 ± 12 (stat) ± 3 (sys) μm

$\Delta\Gamma$ = 0.02 ± 0.05 (stat) ± 0.01 (sys) ps^{-1}

PRL 100, 121803 (2008) **Pred.0.096± 0.039ps^{-1}**

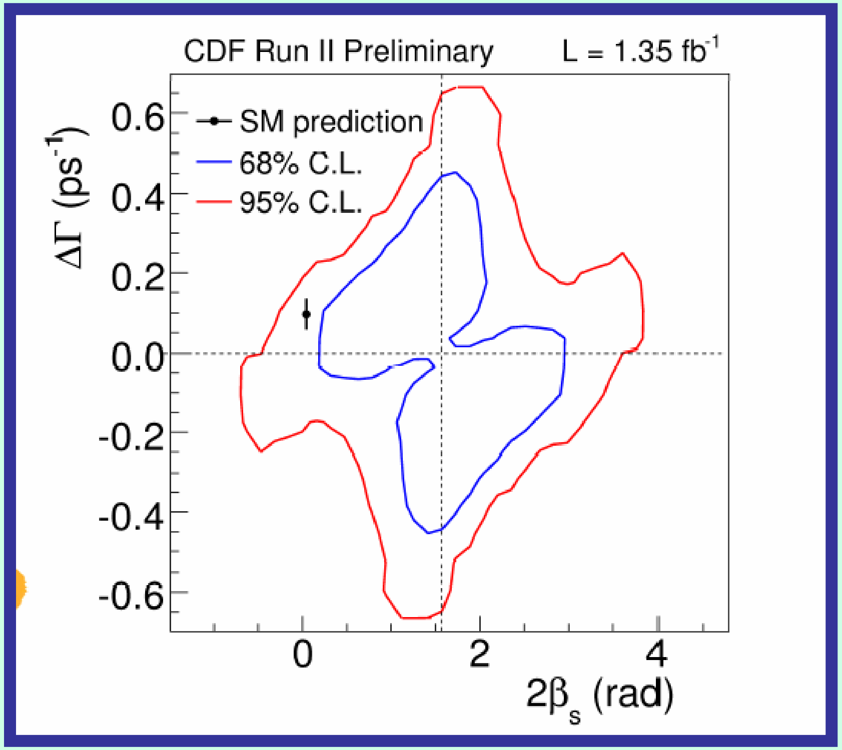
Flavor tagging



OST tuned on B^+

SST tuned on MC, checked on mixing measurement ‘a posteriori’

Results

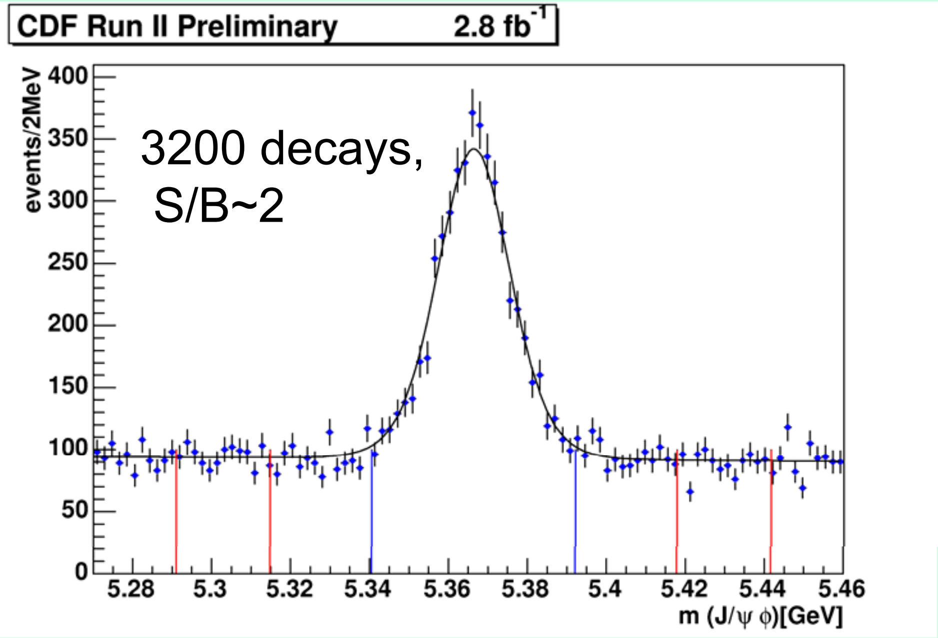


PRL100, 161802(2008)

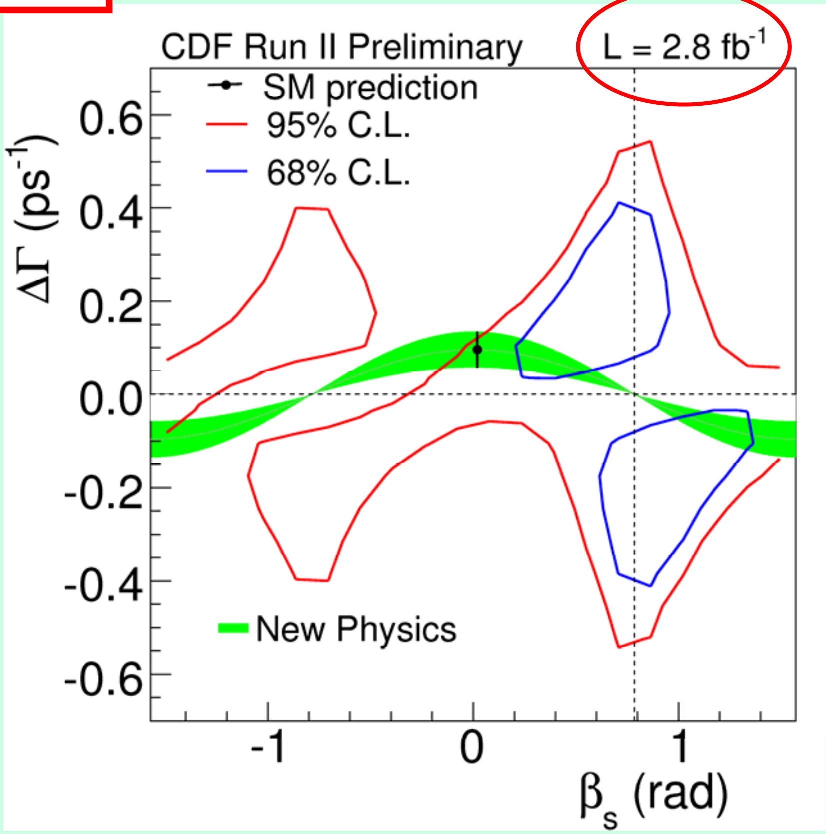
Assuming the SM, the probability of observing a fluctuation as large or larger than observed in data is 15% (1.5σ)

One dimensional: 0.16 < βs < 1.41 at 68% CL

ICHEP update



N.B. Analysis not yet optimized



$0.28 < \beta s < 1.29$ at 68% CL

Increased dataset still hints at larger than SM values!

Consistency with SM decreased 15% → 7% (~1.8 σ)

www-cdf.fnal.gov/physics/new/bottom/080724.blessed-tagged_BsJPsiPhi_update_prelim/

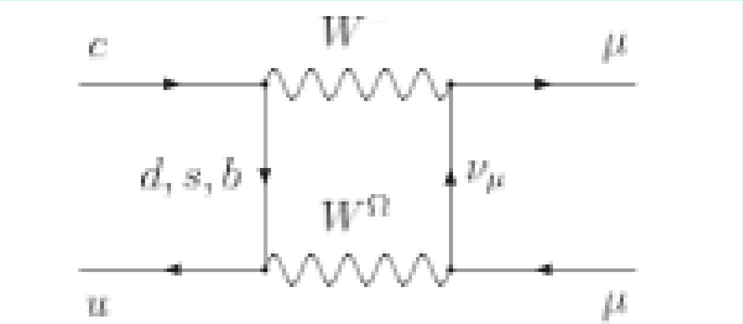
LOOK for 2-body B, D rare decays at CDF:

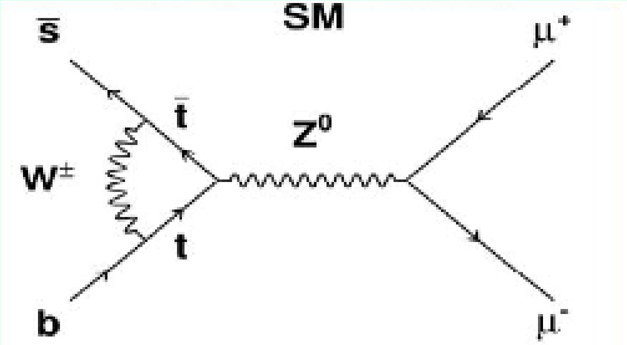
$B^0{}_{d,s} \rightarrow \mu\mu$, $B^0{}_{d,s} \rightarrow e\mu$, $B^0{}_{d,s} \rightarrow ee$ *and* $D^0 \rightarrow \mu\mu$

Ex: SM=> $BR(B_s \rightarrow \mu\mu) \sim 3.8 \times 10^{-9}$ But BR enhanced by $\times 10\text{-}10^3$ by NP

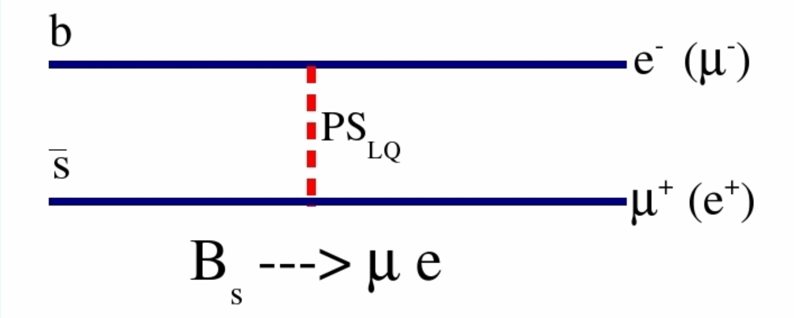
WHY:

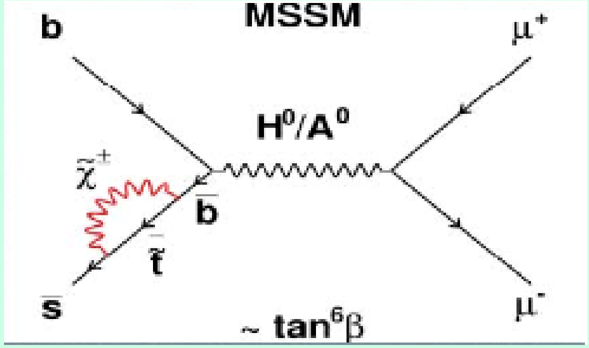
FCNC decays forbidden at tree level, proceed through loops.



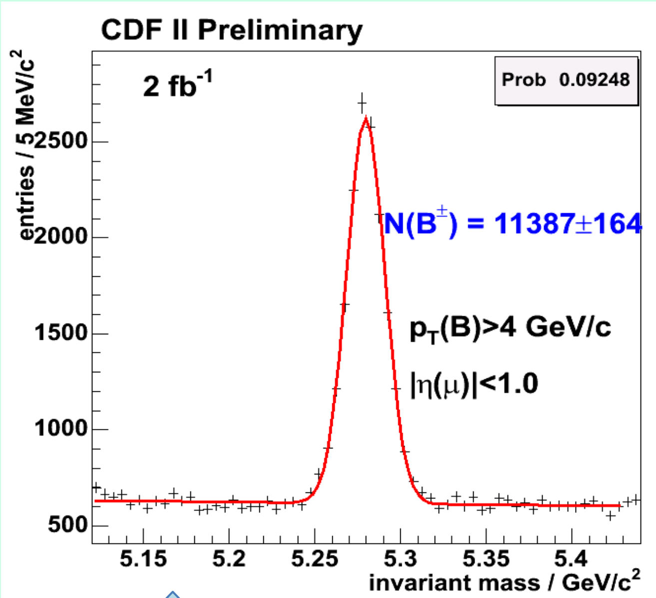


Higher order diagrams highly suppressed, allowing NP to manifest itself.



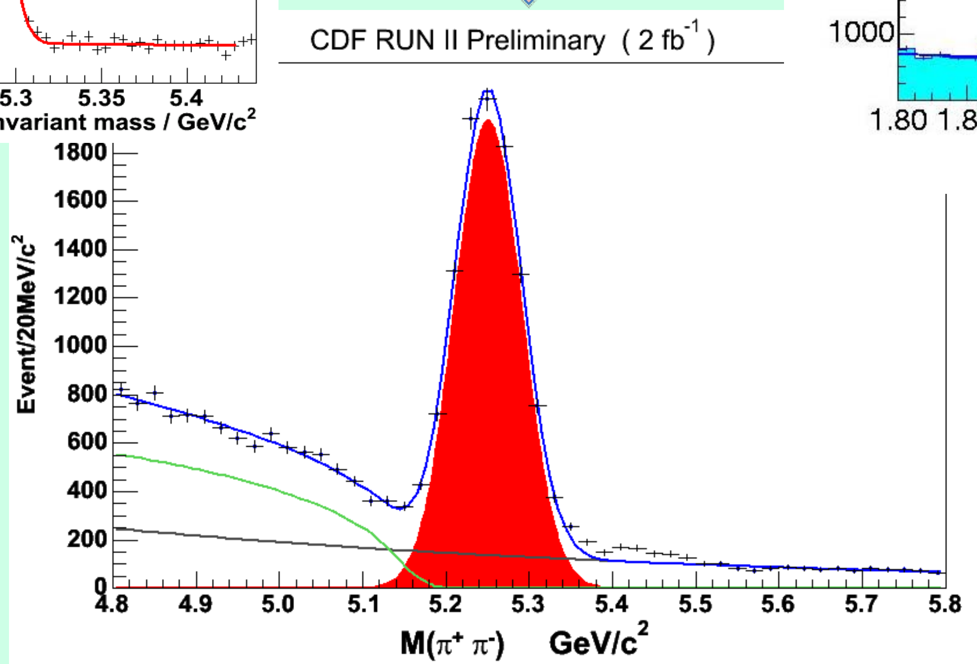


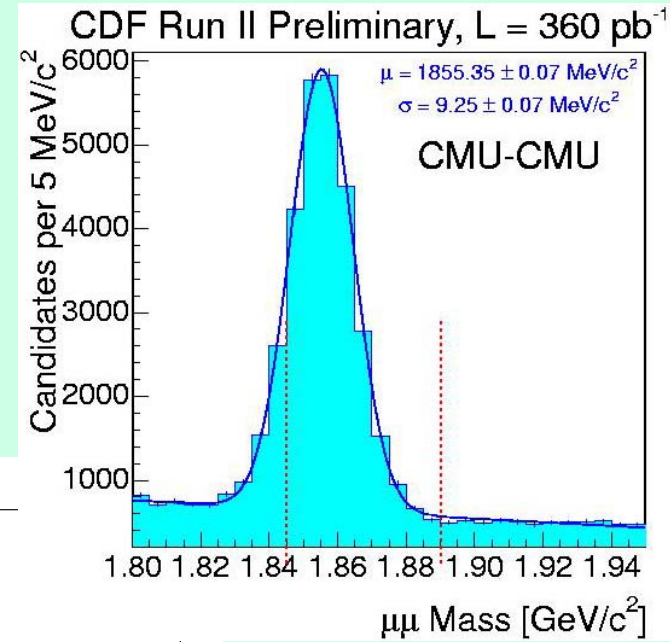
Each search is relative to a normalization mode



$B^+ \to J/\psi\, K^+$
For $B^0_{d,s} \to \mu\mu$

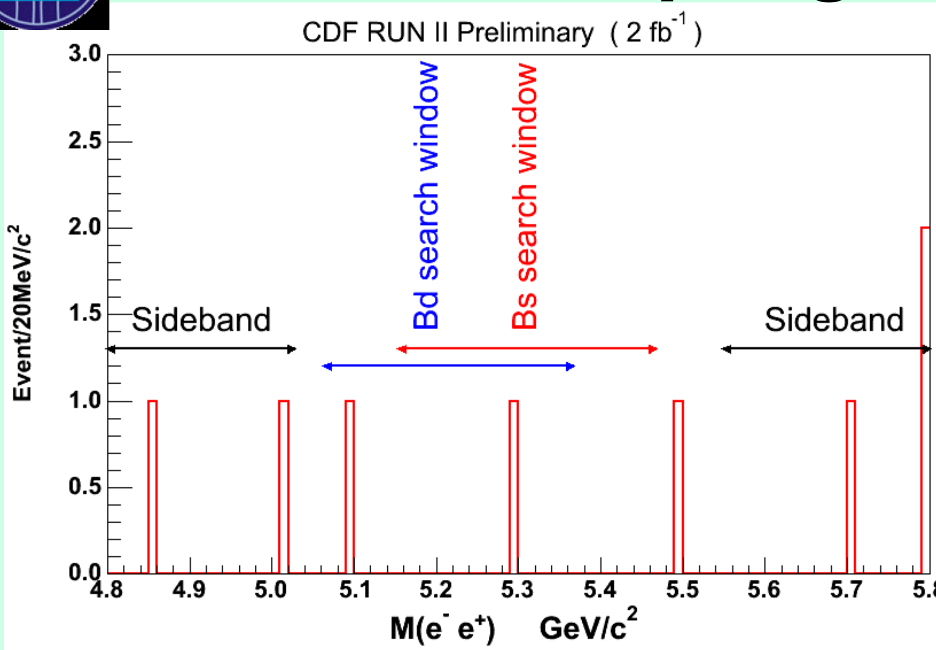
$B^0_d \to K^+\pi^-$ for
$B^0_{d,s} \to ee,\ e\mu$

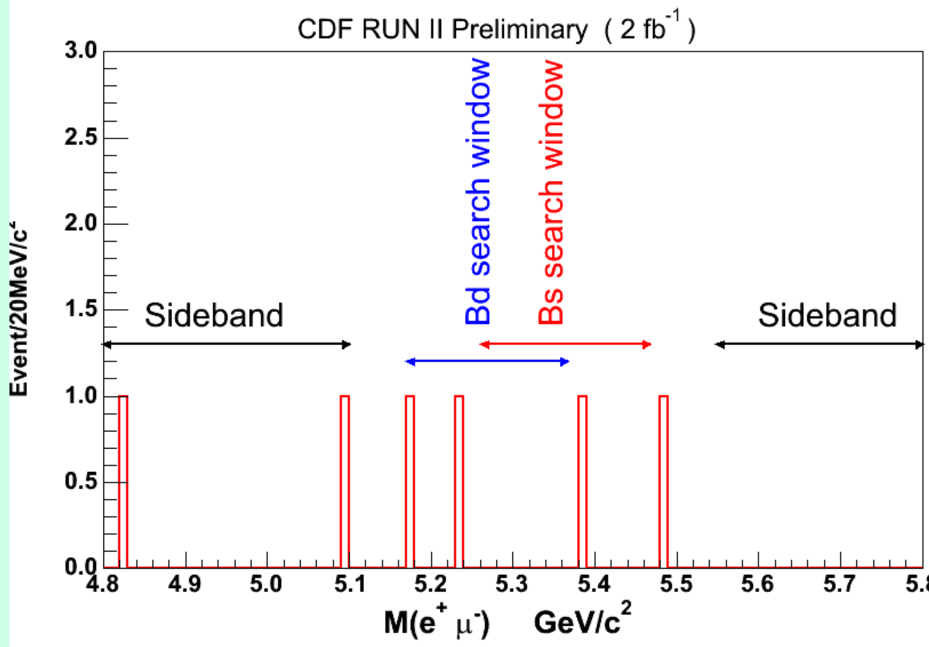




$D^0 \to \pi^+\pi^-$
for $D^0 \to \mu\mu$

$B \rightarrow ee, e\mu$ signal after Lepton ID



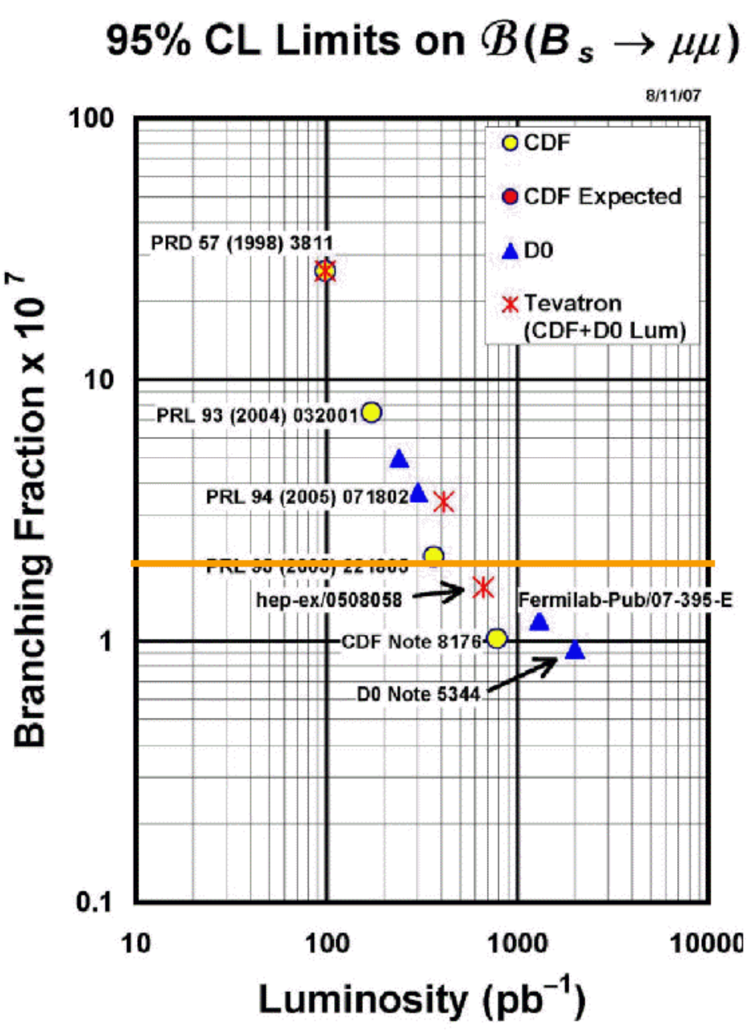


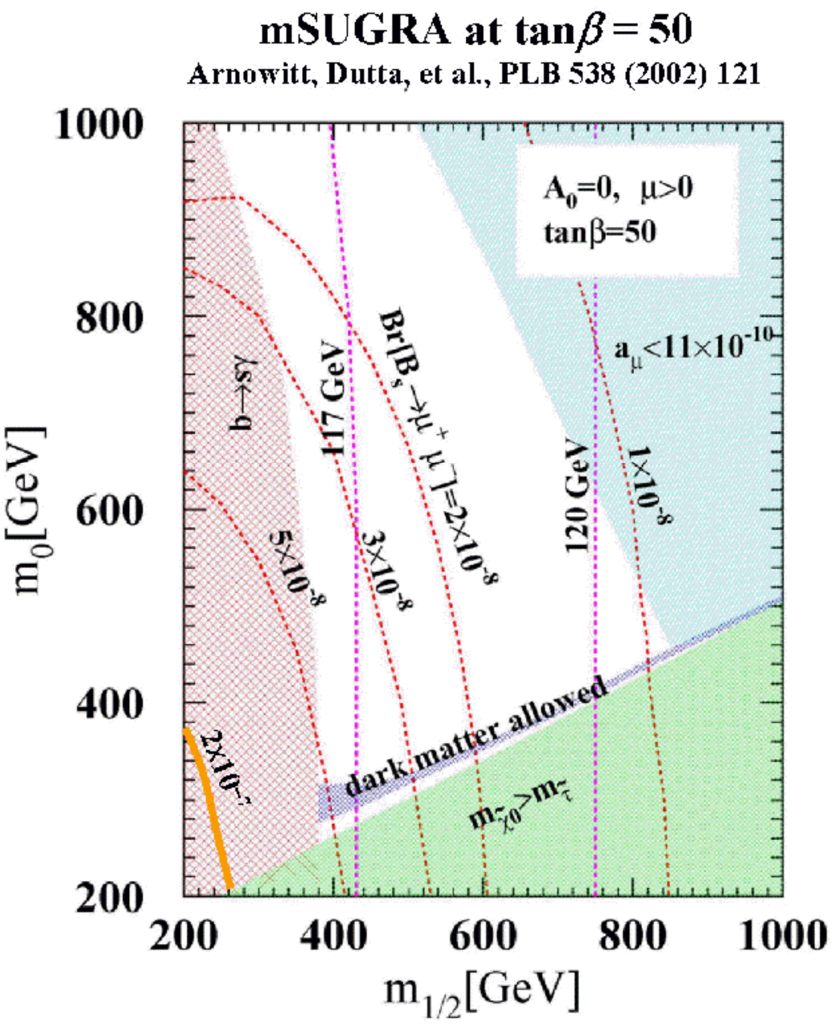
90% (95%) BR limits × 10^8

mode	CDF B.F. limit	Previous best
$B^0_s \rightarrow \mu\mu$	4.7 (5.8)	9.4
$B^0_d \rightarrow \mu\mu$	1.5 (1.8)	3.9
$B^0_s \rightarrow e\mu$	20 (26)	610
$B^0_d \rightarrow e\mu$	6.4 (7.9)	9.2
$B^0_s \rightarrow ee$	28 (37)	5400
$B^0_d \rightarrow ee$	8.3 (10.6)	11.3
$D^0 \rightarrow \mu\mu$	43 (53)	130

World's best limits

$\mathcal{B}(B_s \to \mu\mu)$ and Cosmological Connection





CDF-98 at about 10^3 from SM CDF-08 at about only a factor 10!

- **ELECTROWEAK (EWK) SECTOR**

  W mass

  double boson couplings

Very precise m_W measurement: motivation

The EWK gauge sector of the SM is constrained by 3 precisely known parameters:

$\alpha_{EM}(M_Z) = 1/127.918\ (18)$

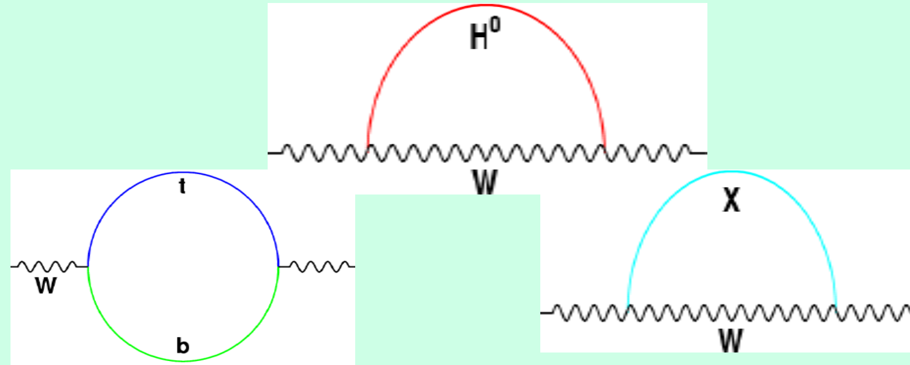
$G_F = 1.16637\ (1) \times 10^{-5}\ GeV^{-2}$

$M_Z = 91.1896\ (21)\ GeV$

At tree level these parameters are related to MW:

$M^2_W = \pi\alpha_{EM}/\sqrt{2}G_F \sin 2\theta_W$

θ_W = weak mixing angle defined by: $\cos\theta_W = M_W/M_Z$



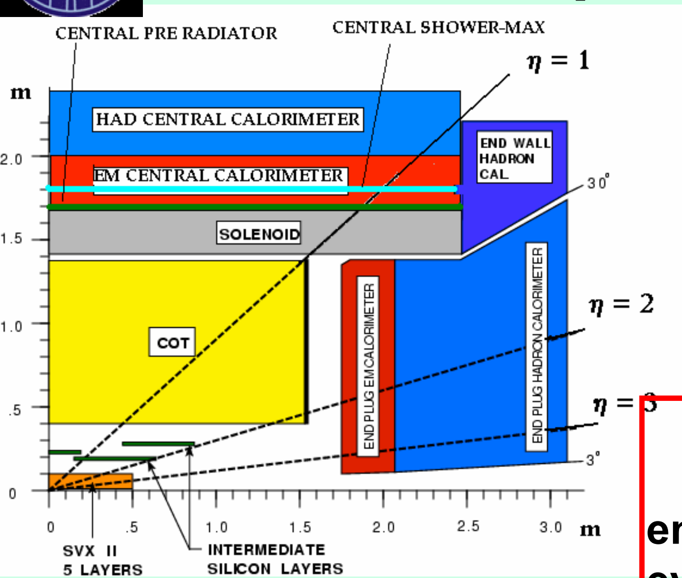
Radiative corrections due to heavy quarks, Higgs loop and BSM, motivate introducing ρ-parameter: $M_W = \rho\,[(M_W(\text{tree})]^2$ with the predictions:

$$\rho - 1 \sim M^2_{top} \sim \text{In}\ M_{Higgs}$$

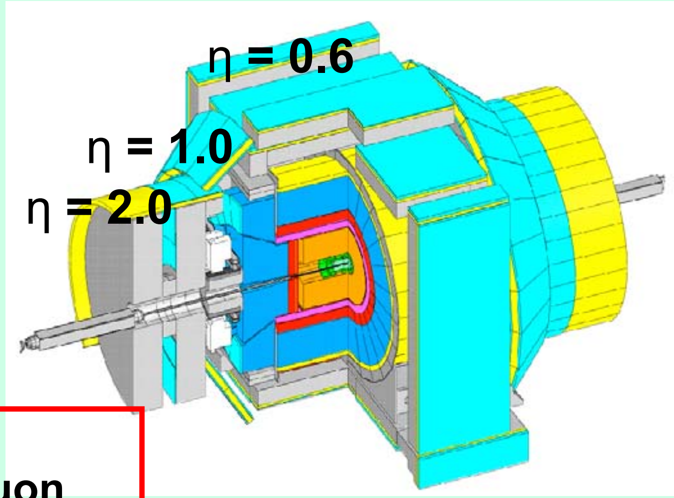
In conjunction with M_{top}, M_W constraints M_{Higgs} and possibly new particles BSM

Progress on δM_W has the biggest impact on Higgs constraint

EWK precision measurements

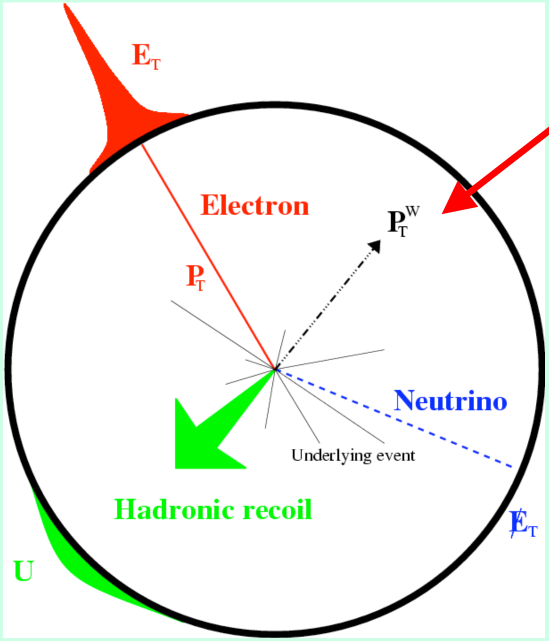


Drift chamber to |η|<1
Further tracking from Si
Calorimeter to |η|<3
Muon system to |η|<1.5



W selection:

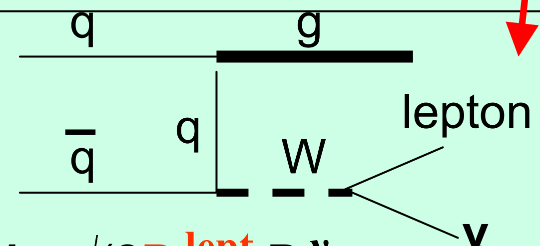
exactly one electron or muon
energy imbalance in reconstructed event, associated with neutrino



<u>At Tevatron</u>: qq dominates (80%); initial state gluon radiation is O(10 GeV), measured as soft "hadronic recoil" in calorimeter (calib. ~1%)

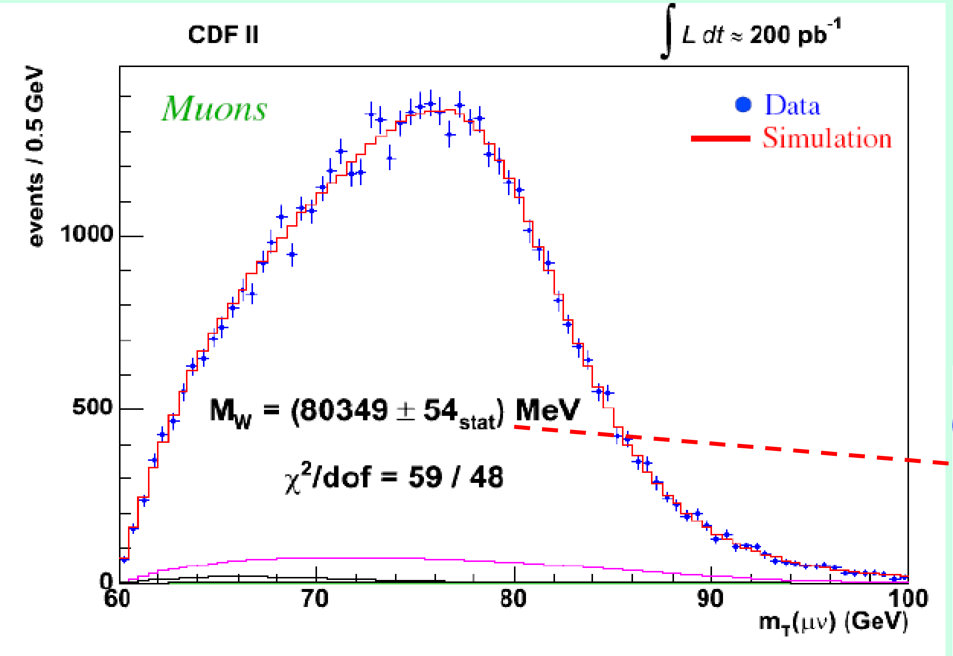
Pollutes Wmass info:

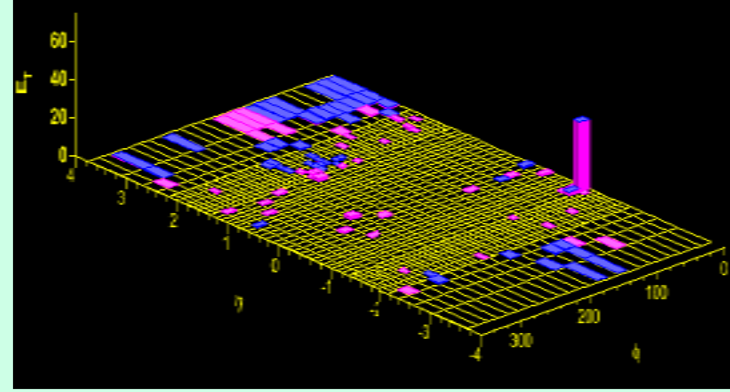
but: $P_T(W) \ll M_W$



$M_t = \sqrt{(2 P_t^{lept} P_t^{\nu} [1-\Delta\Phi])}$

P_t^{lept} carries most of W mass info (measured at 0.03%)

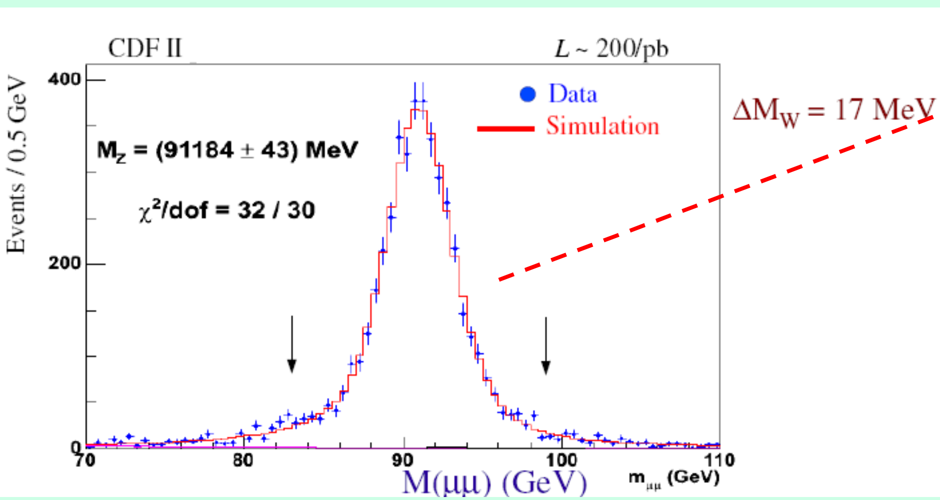




Transverse Mass Fit Uncertainties (MeV)

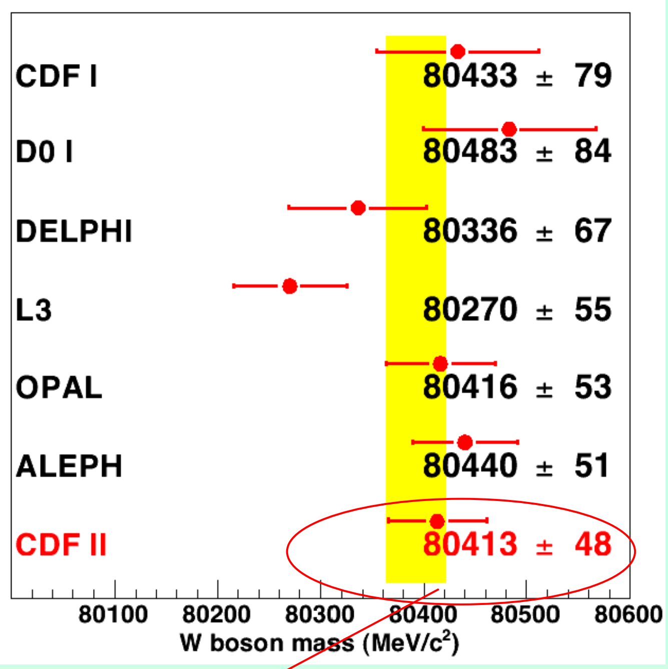
(CDF, PRL 99:151801, 2007; Phys. Rev. D 77:112001, 2008)

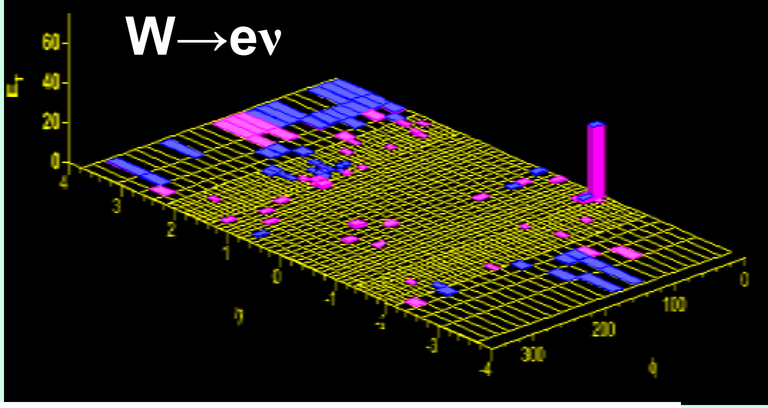
	electrons	*muons*	*common*
W statistics	48	54	0
Lepton energy scale	30	17	17
Lepton resolution	9	3	-3
Recoil energy scale	9	9	9
Recoil energy resolution	7	7	7
Selection bias	3	1	0
Lepton removal	8	5	5
Backgrounds	8	9	0
pT(W) model	3	3	3
Parton dist. Functions	11	11	11
QED rad. Corrections	11	12	11
Total systematic	39	27	26
Total	62	60	

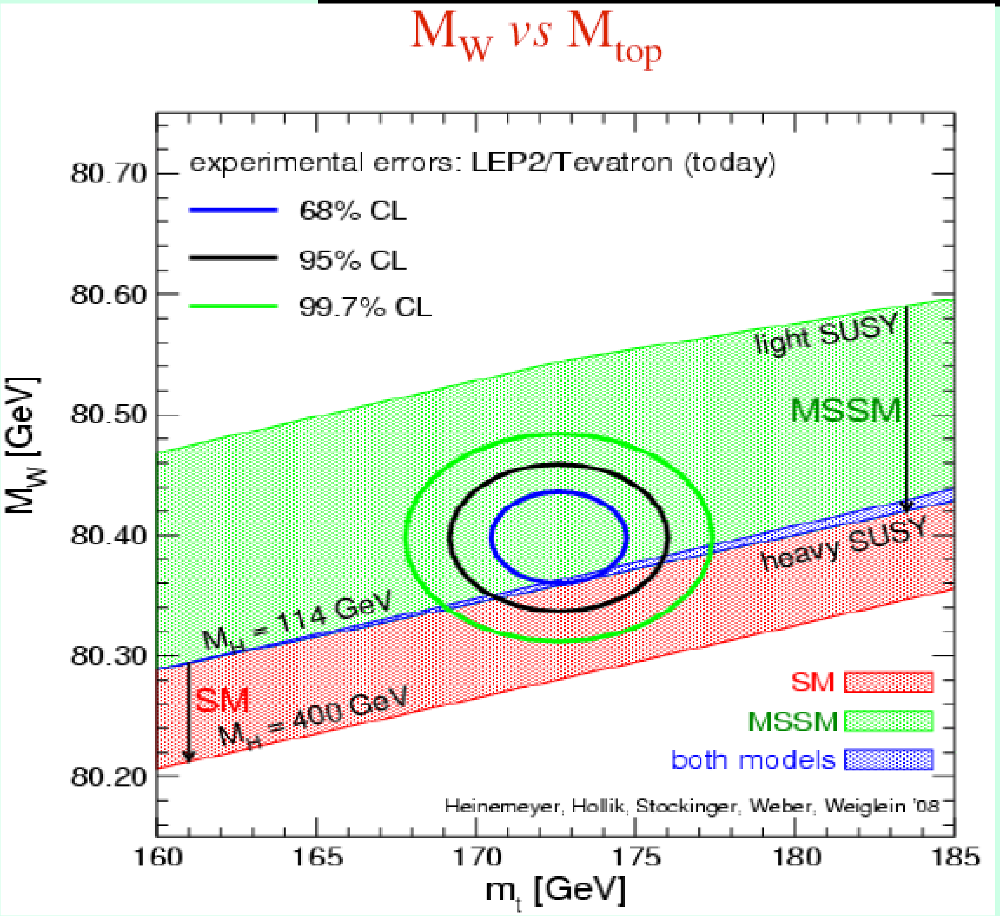


$\Delta M_W = 17$ MeV

W mass latest result

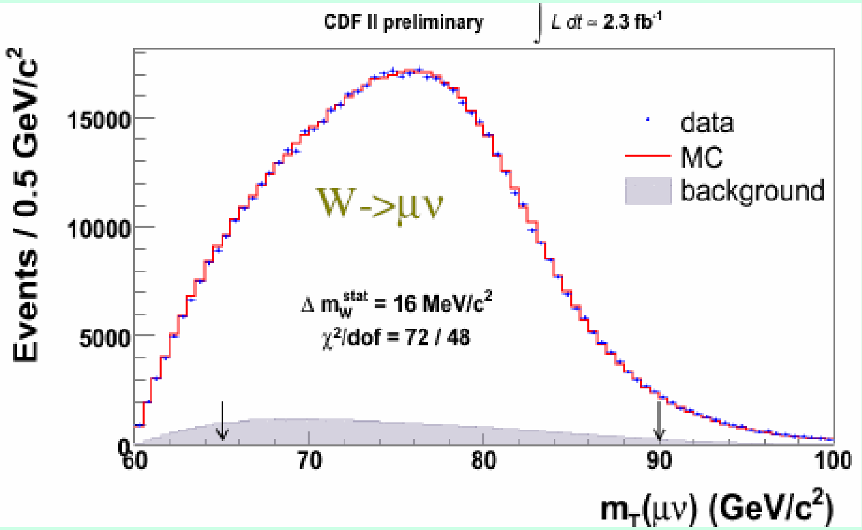


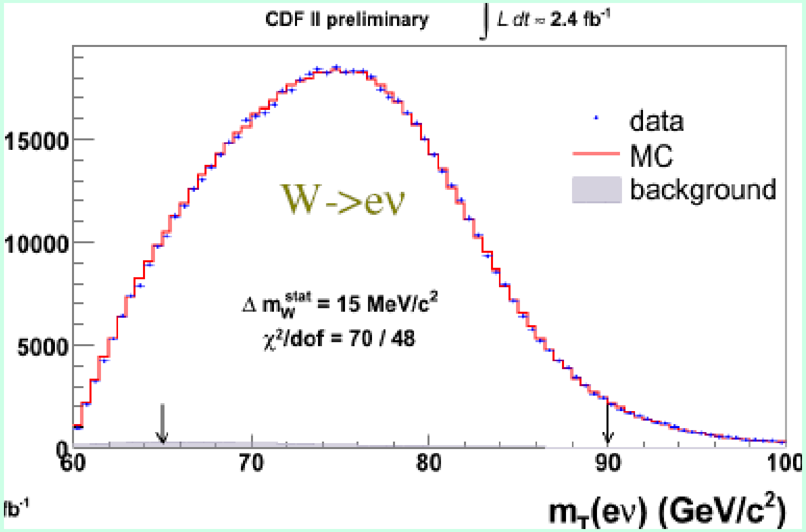


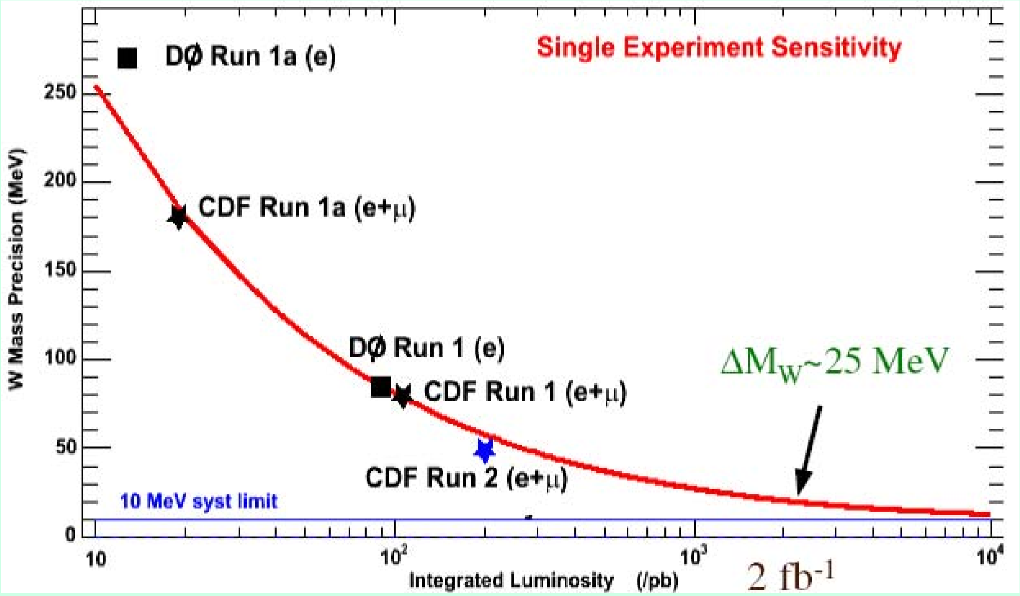


World's best single experiment measurement based on 200 pb^{-1}

Preliminary studies on δM_W & M_W with 2.4 fb^{-1}







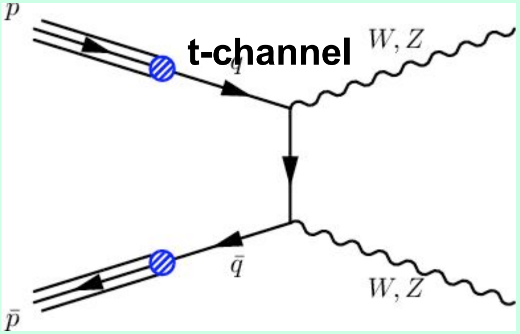
Recoil resolution not significantly degraded at higher instantaneous luminosity.

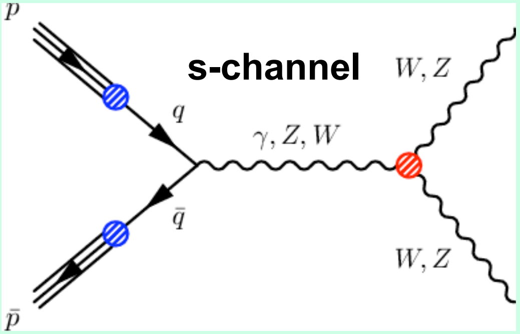
Statistical errors on transverse mass fits are scaling with statistics

GOAL: $\delta M_W \sim$ 20MeV

Forbidden triple gauge couplings (TGC)

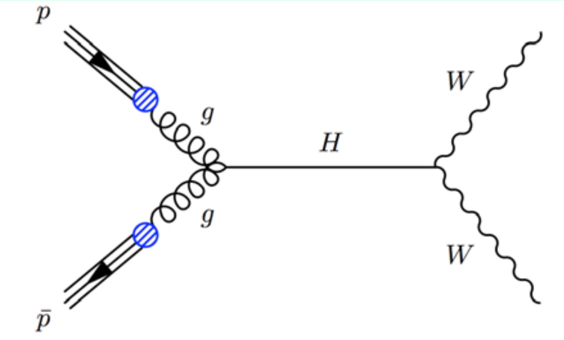
1) why to study Diboson production ?



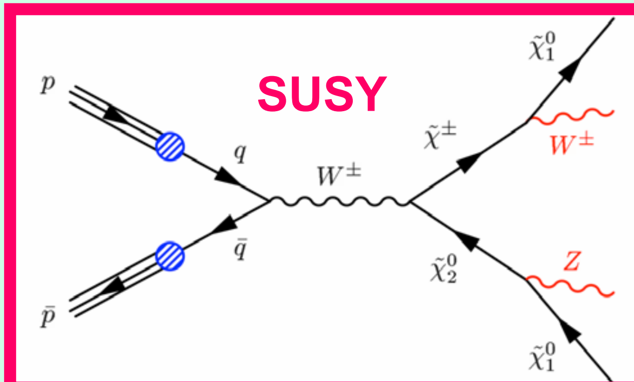


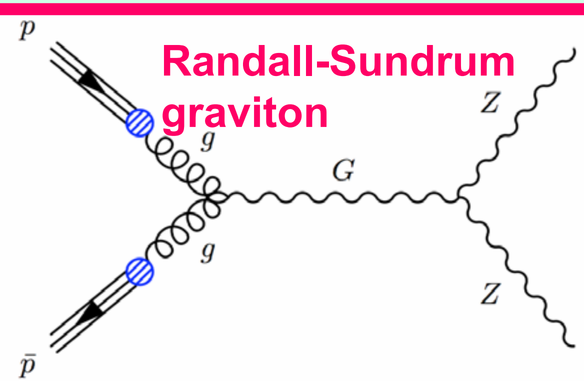
$$q\bar{q}' \to W^{(*)} \to W\gamma : WW\gamma$$
$$q\bar{q}' \to W^{(*)} \to WZ : WWZ$$
$$q\bar{q} \to Z/\gamma^{(*)} \to WW : WW\gamma, WWZ$$
$$q\bar{q} \to Z/\gamma^{(*)} \to Z\gamma : ZZ\gamma, Z\gamma\gamma$$
$$q\bar{q} \to Z/\gamma^{(*)} \to ZZ : ZZ\gamma, ZZZ$$

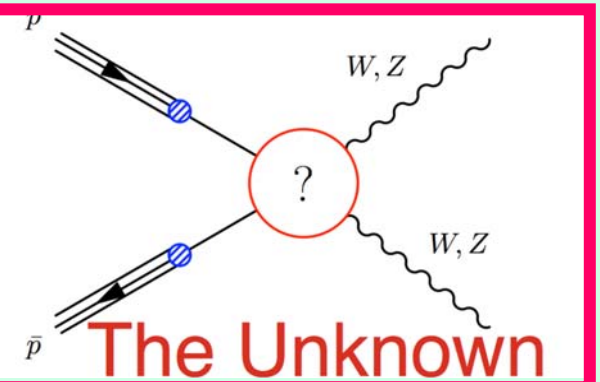
SM



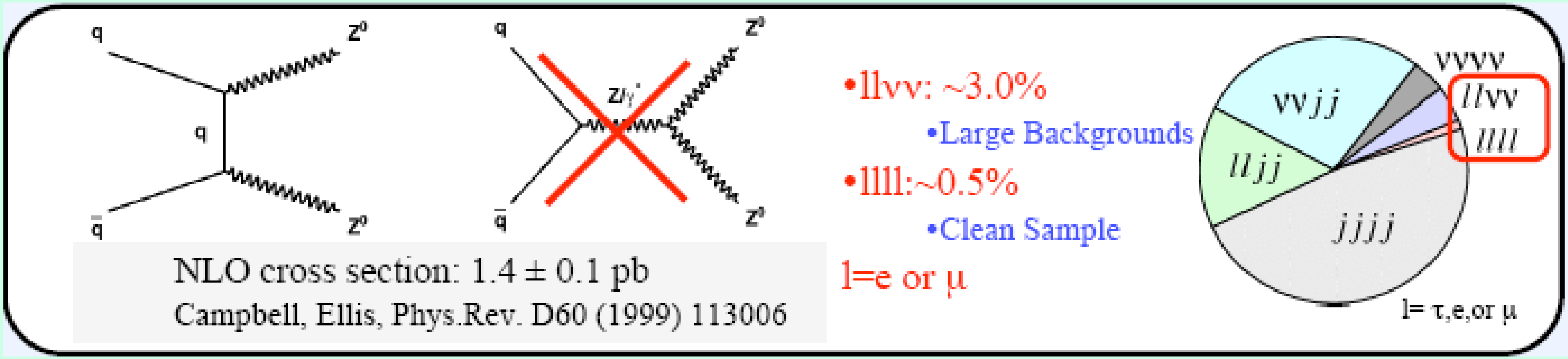
- s-ch. prod. probes non-Abelian structure of SU(2)L⊗U(1)Y
- Tevatron sensitive to different TGCs than LEP higher s
- Important background for Higgs Searches!
- New physics => enhanced rate of diboson production!







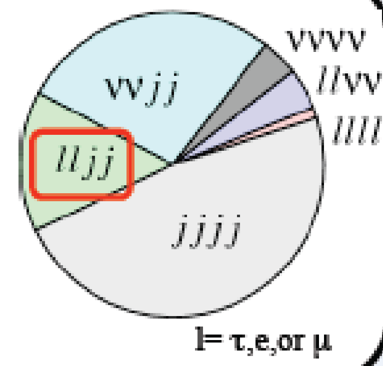
ZZ production at CDF

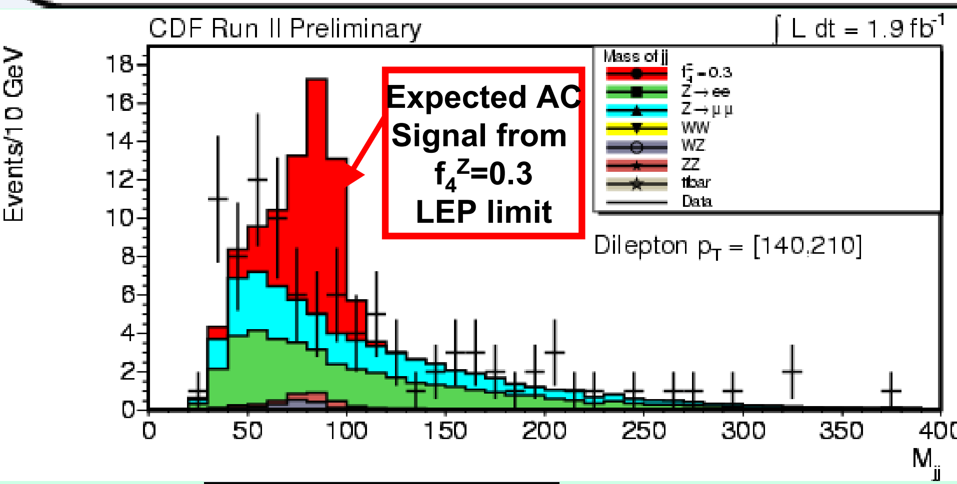


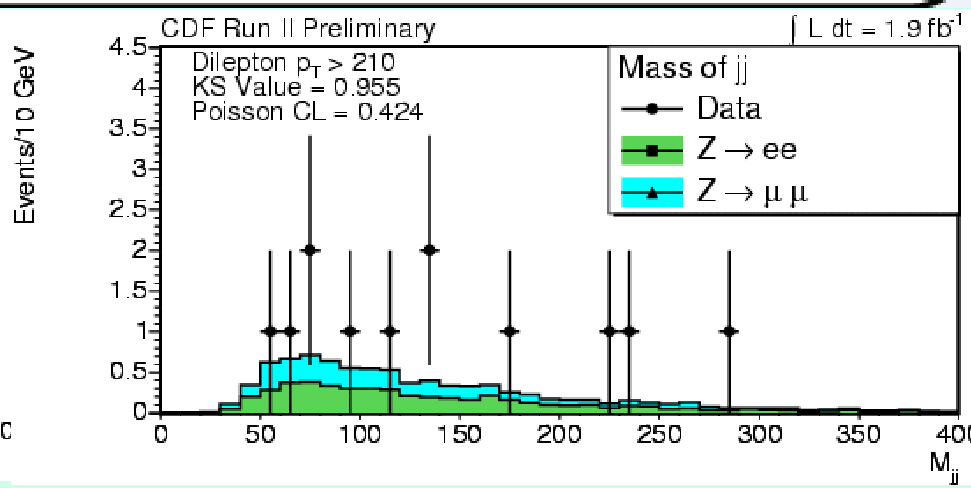
- Demonstrates the ability to measure small cross-section
- ZZZ and ZZγ forbidden by SM => opportunity to look for new Physics
- Training camp for Higgs searches

ZZZ/ZZγ anomalous coupling

- CDF @ 1.9 fb^{-1}: ZZ→lljj channel
- Higher Branching ratio, large Z + jets background
- Signal from anomalous ZZZ/ZZγ couplings expected at large $P_T(Z)$
- Use dijet mass spectrum in high $P_T(Z)$ regions to constrain potential contribution from anomalous couplings







Λ=1.2 TeV
$-0.12 < f_4^Z < 0.12$
$-0.13 < f_5^Z < 0.12$
$-0.10 < f_4^\gamma < 0.10$
$-0.11 < f_5^\gamma < 0.11$

95% C.L. limits

Bin	95% CL Cross-Section (pb)
Med	0.28
High	0.077

- **TOP: Is the top standard?**

  Study of top properties

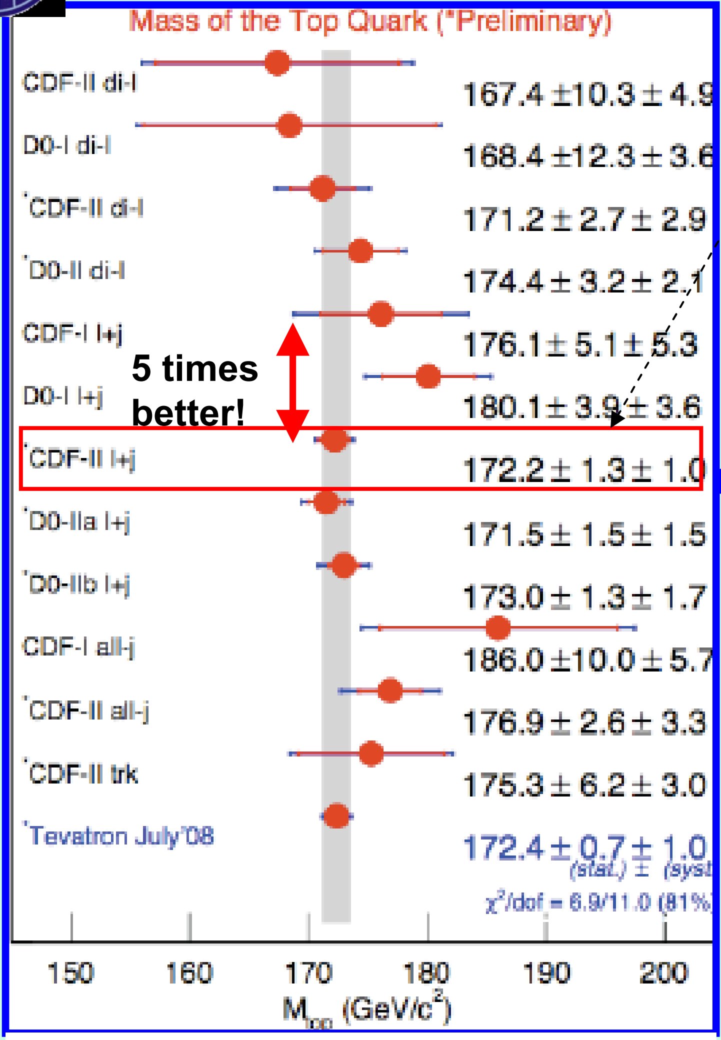
  Mass

  Production modes

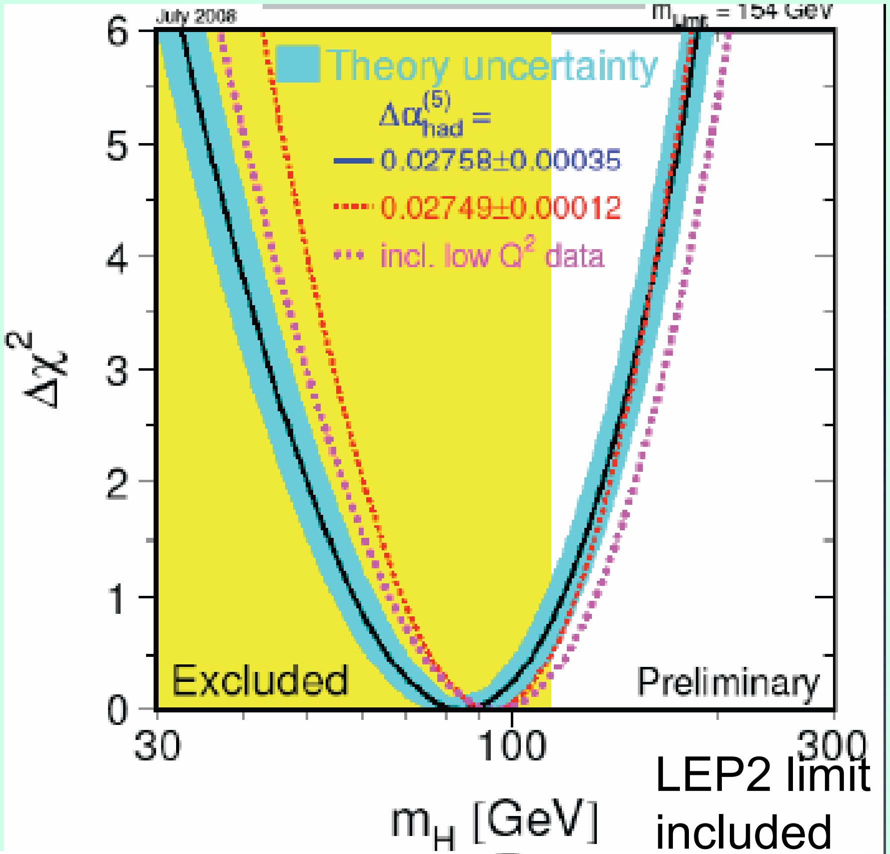
  Helicity

  Decays

Top Mass: a crucial parameter



Lepton+jets, great progress: especially work on JES



LEP2 limit included

$m_H < 154$ GeV @ 95% C.L.

$m_t = 172.4 \pm 0.7 \pm 1.0$ GeV

0.7 % precision

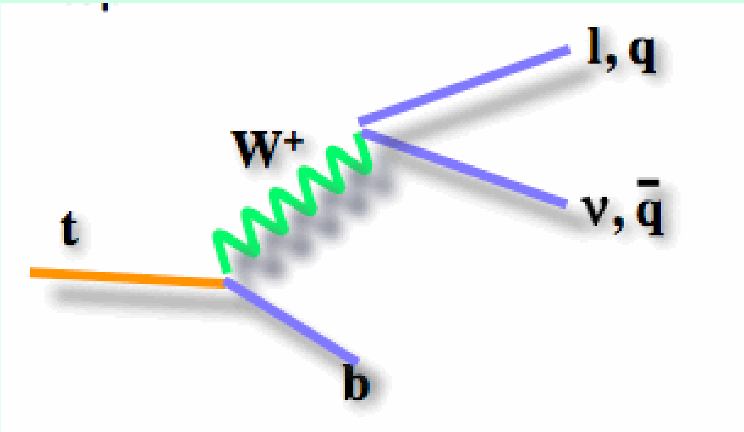
$\delta M_{top} = 1.4$ GeV => $\delta M_H / M_H = 12\%$

Equivalent $\delta M_W = 8$ MeV for same M_H constraint

Is the top standard ?

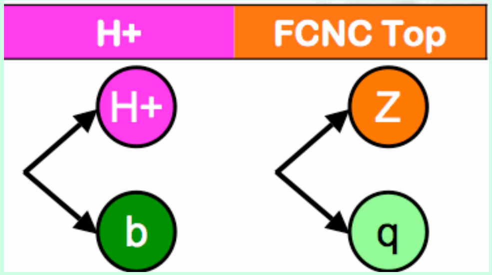
Within the standard model the top quark decays into Wb

Probing the nature of the t → Wb vertex, with helicity measurement



Can the top decay into other particles:

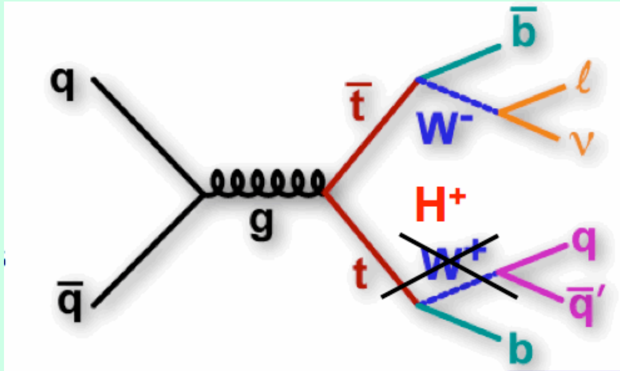
- Br(t→Wb)/Br(t→Wq)
- ***Search for charged Higgs***
- ***Search for FCNC top decays***
- Search for Invisible Top Decays



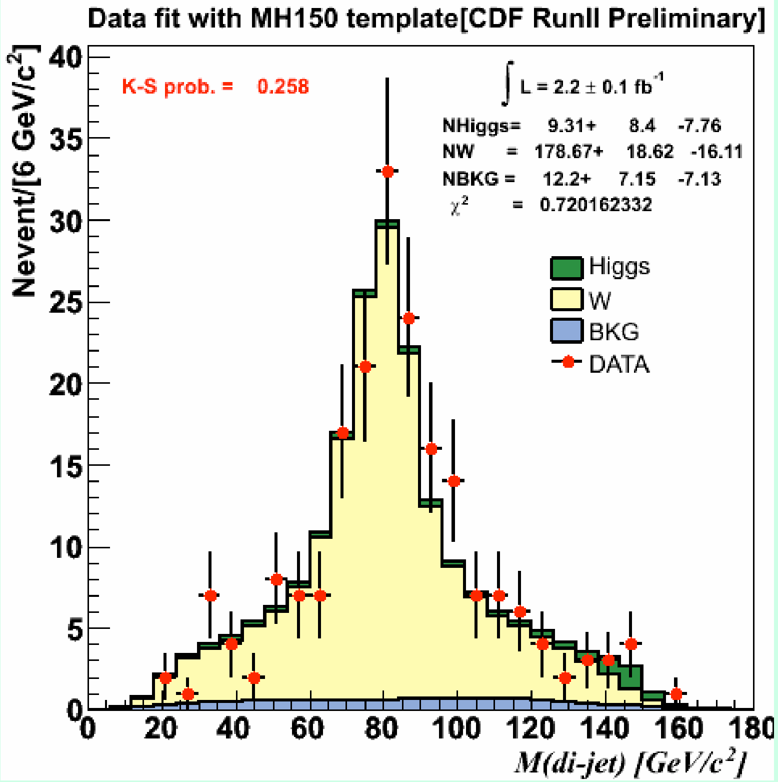
All these measurements are high precision measurements

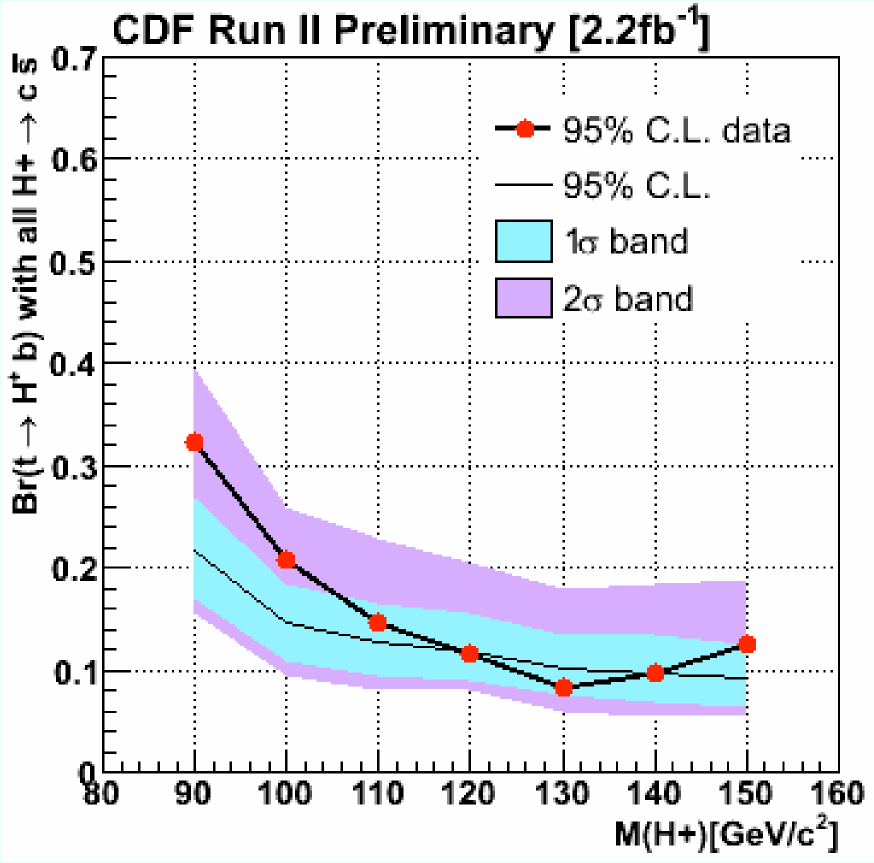
Thus CDF has entered a new phase in the Top Physics

Search for charged Higgs in top decay



Explore the possibility that $t \to H^+ b$
With subsequent decay of $H^+ \to \bar{c}\, s$
Reconstruct event kinematics





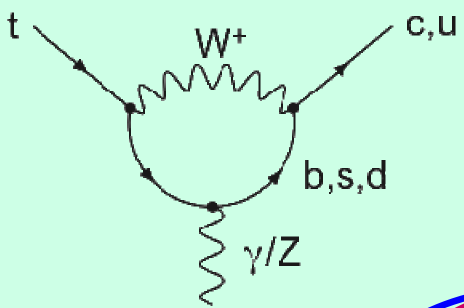
Z! Top: interesting way to look for H± Z!

Search for Top Flavour Changing Neutral Currents

No FCNC interactions at tree level in SM. Further suppression: GIM mechanism, CKM suppression. Top FCNC extremely rare: BR($t \to Zq$)=O(10^{-14})

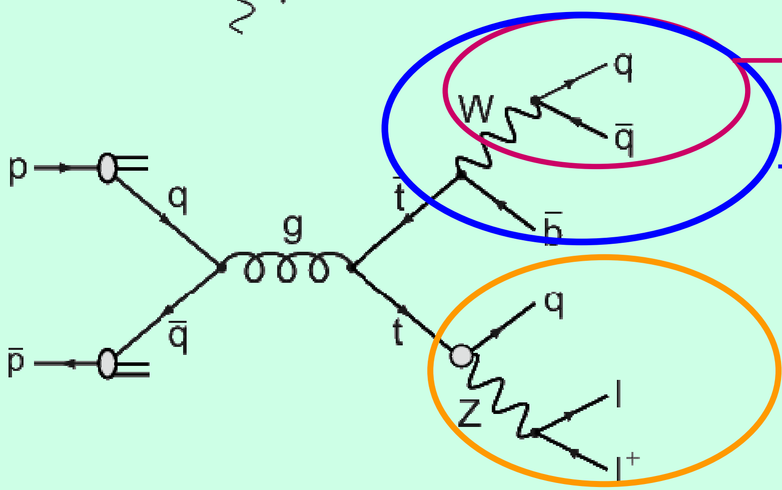
BSM models predict higher BR, up to O(10^{-4})

FCNC through Penguin diagram



Dominant background: Z + 4 jets

Reconstruct event kinematics:

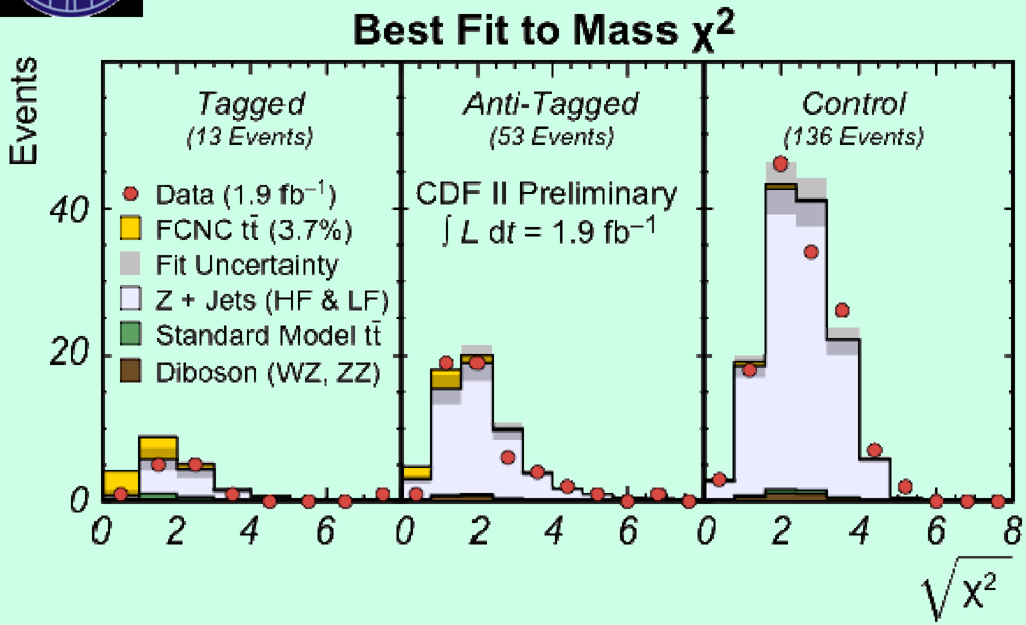


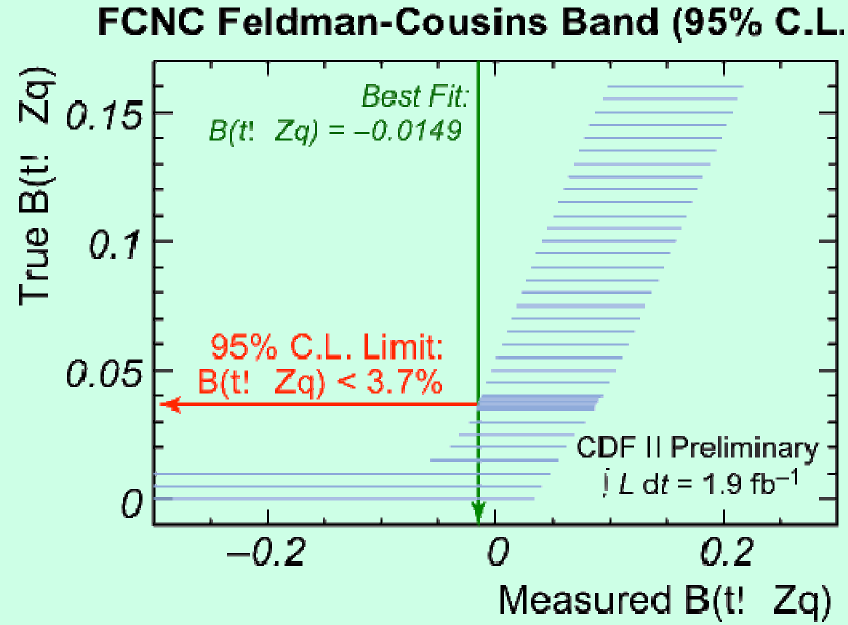
$\chi 2$ of mass reconstruction:

$$\left(\frac{m_{W,\mathrm{rec}} - m_{W,\mathrm{PDG}}}{\sigma_W}\right)^2 + \left(\frac{m_{t\to Wb,\mathrm{rec}} - m_t}{\sigma_{t\to Wb}}\right)^2 + \left(\frac{m_{t\to Zq,\mathrm{rec}} - m_t}{\sigma_{t\to Zq}}\right)^2$$

Any signal at the Tevatron: New Physics

Top FCNC results with 1.9 fb-1





Limit on B(t→Zq) obtained from template fit to mass χ^2distribution

- Simultaneous fit to two signal regions and one control region
- Feldman-Cousins limit with systematic uncertainties

New world's best limit on B(t→Zq):

Best published limit (13.7%) improved by factor of 3.5

BR(t→Zq) < 3.7%
95% C.L.

The Higgs sector:

QUESTION#1: Is there a Higgs at all?

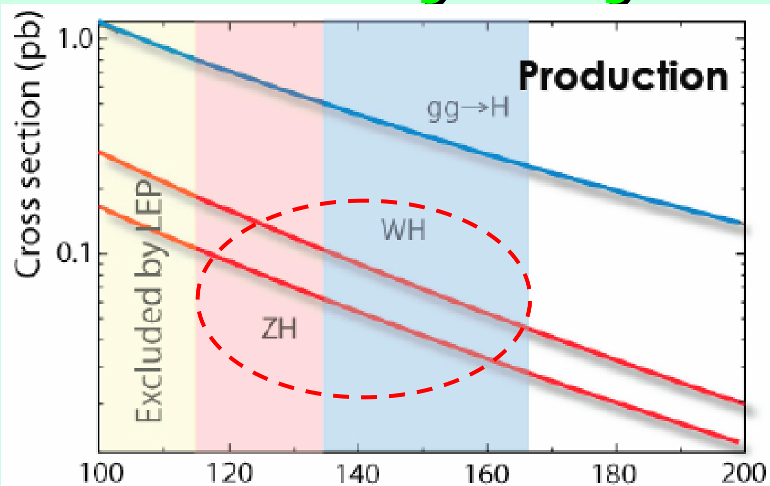
QUESTION#2: IF YES, what mass?

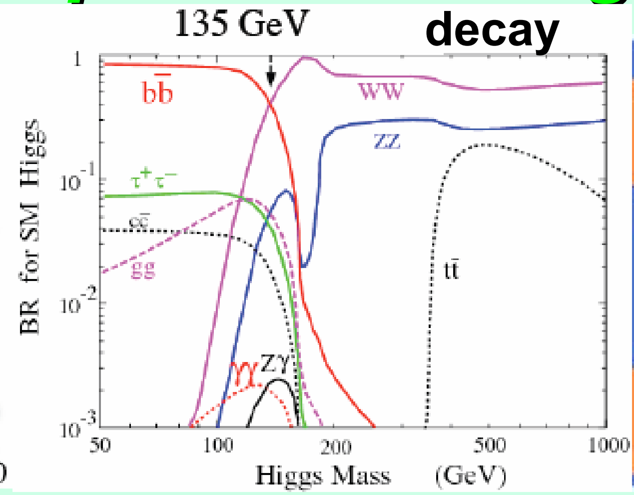
and how many there are?

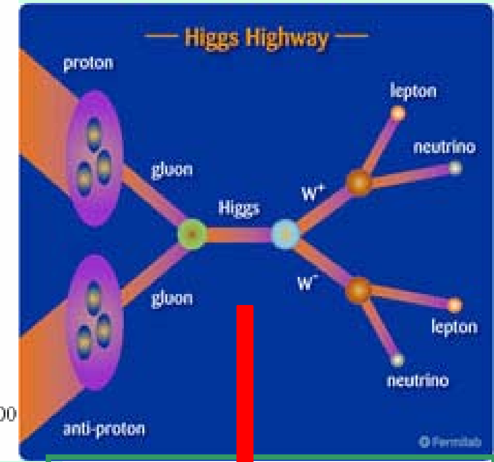
Tevatron should be able to answer, at least partially, to these questions by searching for a light Higgs

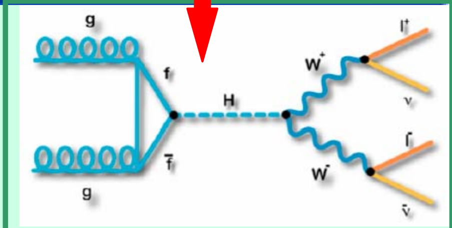
The many ways CDF is looking a light Higgs

The many ways to produce a Higgs at CDF

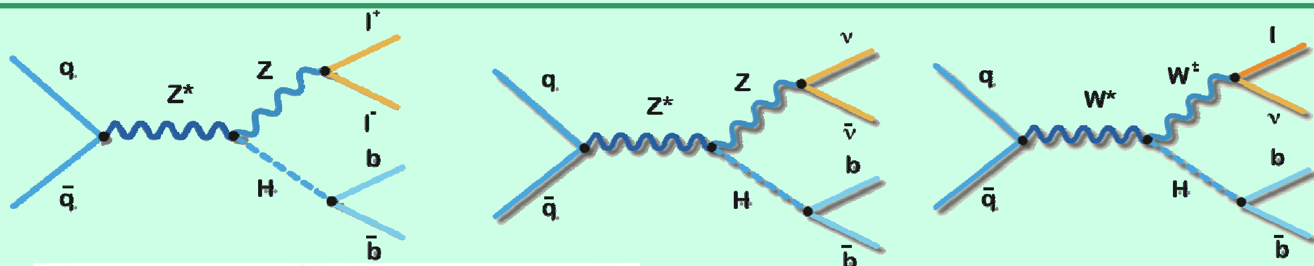


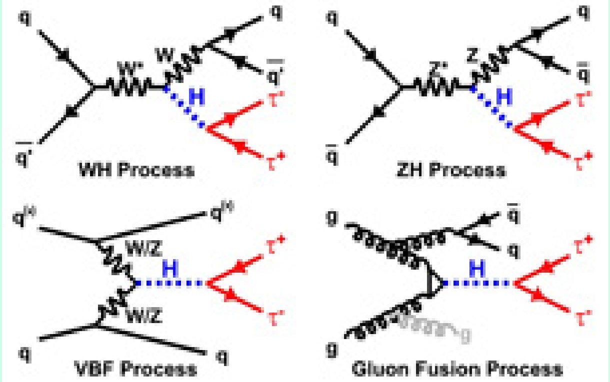


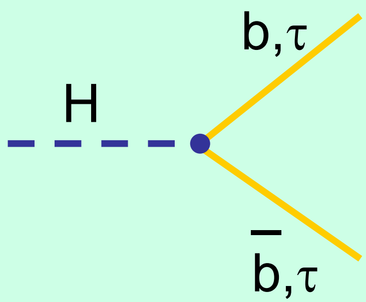




gg→H→bb dominates but huge QCD bkgd **=> close to IMPOSSIBLE**



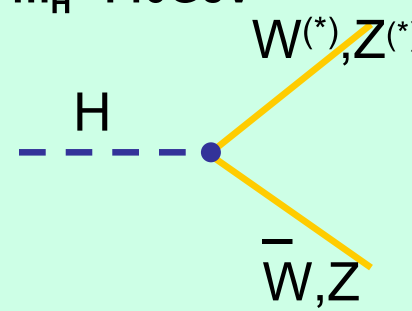




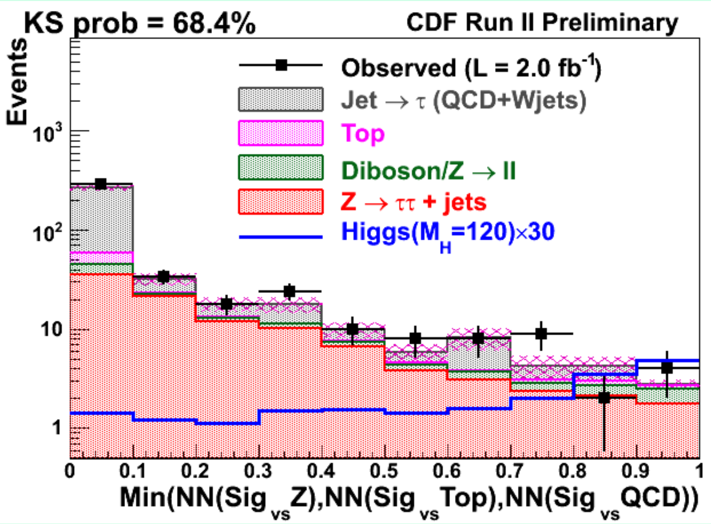
m_H<140GeV

WH→lνbb
ZH→llbb
VH→ννbb,
ν(l)bb
VH→qqbb
H→ττ(+jets)

m_H>140GeV

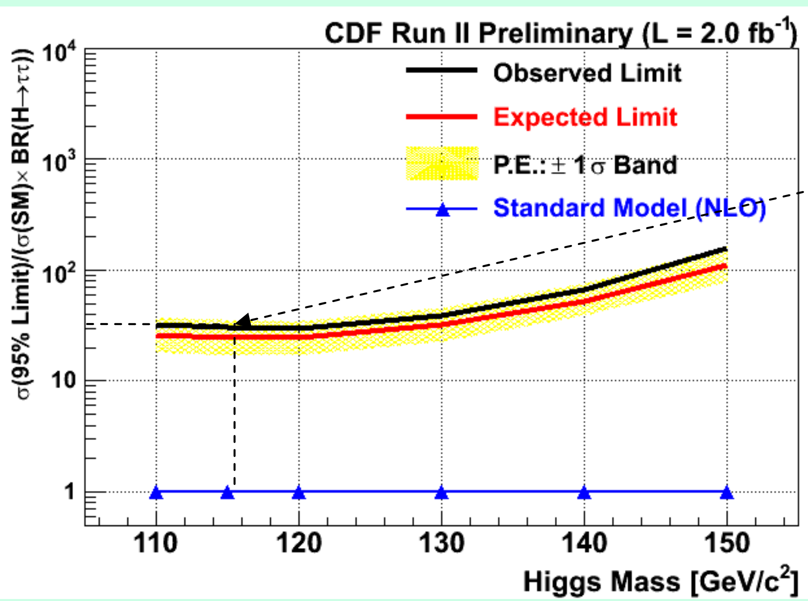


Neutral SM Higgs into τ-leptons



Small Backgrounds ($\int \mathcal{L} dt = 1.9\,\mathrm{fb}^{-1}$)				
Sample	Cross Section (pb)	Events Tagged	Events Anti-Tagged	Events Control
SM $t\bar{t}$	8.8±1.1	1.7±0.2	0.7±0.1	1.8±0.2
WZ	3.96±0.06	0.2±0.1	1.4±0.1	2.1±0.1
ZZ	3.40±0.25	0.3±0.1	1.1±0.1	1.8±0.1

Important to look at different decay mode (i.e. H→ττ, not only H→ bb).

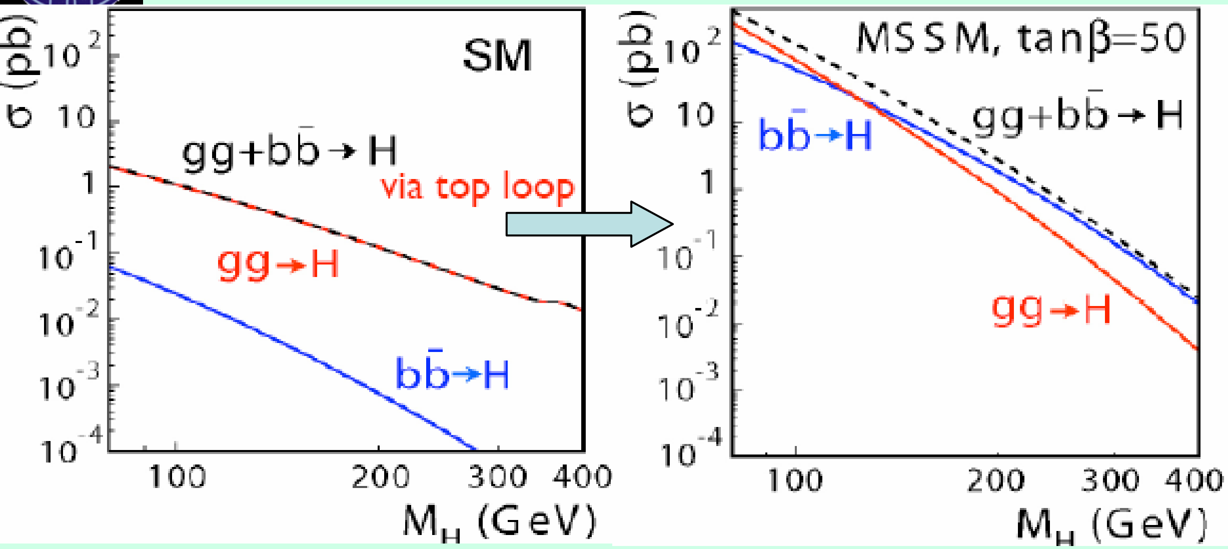


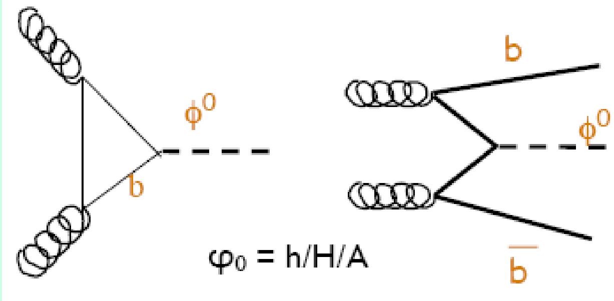
95% CL Limit in σ/SM
CDF: 30.5 (24.8) M_H= 115GeV/c^2

Analysis optimized for SM Higgs, but sensitive to non SM Higgs.

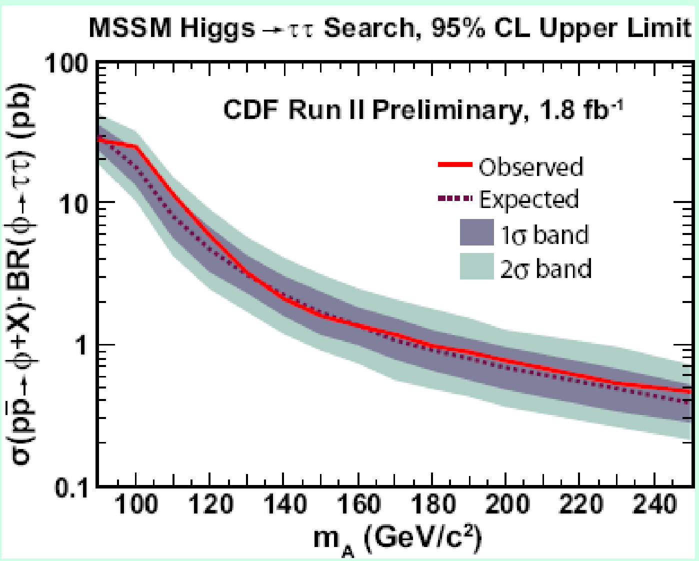
MSSM predicts a much higher H-rate for large tanβ in gg fusion, especially in τ-decay.

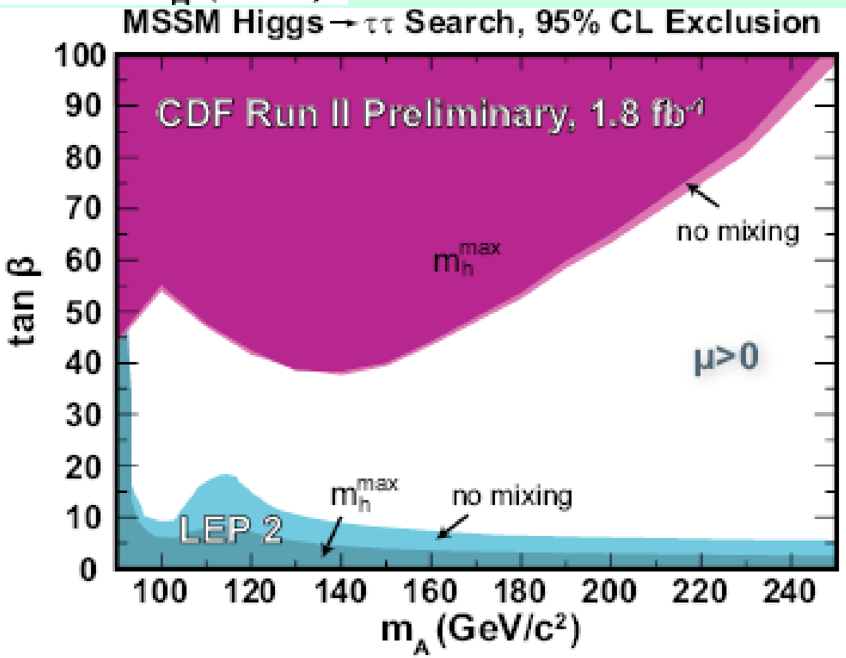
Search for a SUSY Higgs into 2 τ's





- σ(MSSM) ~ σ(SM) x $\tan^2\beta$
- ττ signal: lower background
- τ-BR increases with tanβ





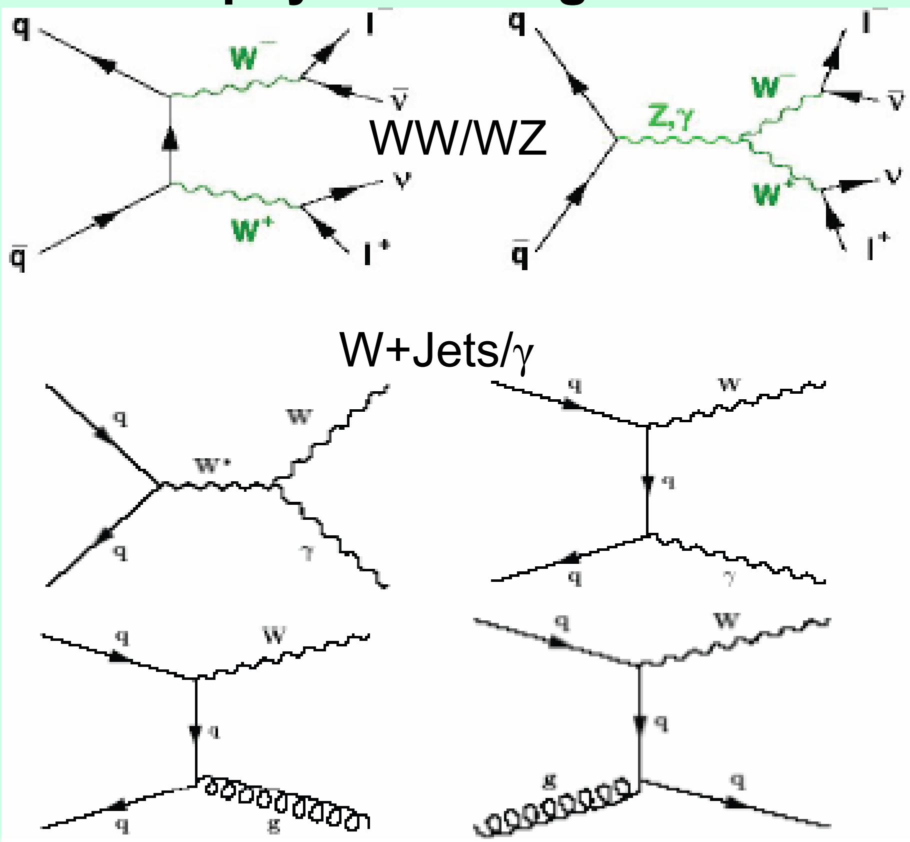
Summary of present results for low SM mass Higgs at CDF

$m_H=115\ GeV/c^2$	Channel	95% C.L. Limits $\sigma\cdot BR/SM$ obs (exp)
	$WH\rightarrow l\nu bb$ (NN)	5.0 (5.8) $2.7fb^{-1}$
	$WH\rightarrow l\nu bb$ (ME+BDT)	5.7 (5.6) $2.7fb^{-1}$
	$WH\rightarrow \tau\nu bb$ (NN)	-
	$VH\rightarrow qqbb$ (ME)	37.0 (36.6) $2.0fb^{-1}$
	$ZH\rightarrow llbb$ (NN)	11.6 (11.8) $2.4fb^{-1}$
	$ZH\rightarrow llbb$ (ME) ($m_H=120\ GeV/c^2$)	14.2 (15.0) $2.0fb^{-1}$
	$VH\rightarrow \nu\nu/(l)bb$ (NN)	7.9 (6.3) $2.1fb^{-1}$
	$ttH\rightarrow l\nu bbbbqq$	-
	$H\rightarrow\gamma\gamma$	-
	$H\rightarrow\tau\tau$	30.5 (24.8) $2.2fb^{-1}$

Courtesy Bernd Steltzer

The many ways to search for Higgs at CDF the high mass case: $H \rightarrow WW^* \rightarrow l\nu l\nu$

The physics backgrounds



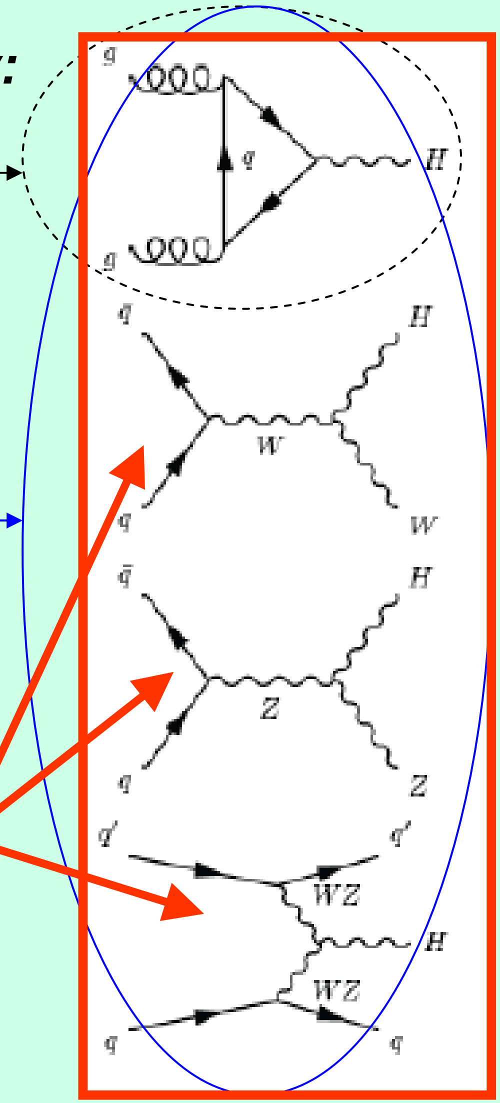
And: Drell-Yan, ttbar, single top, Multijets
all these processes are well measured

Analyse strategy:

0 jet events

1 jet events

≥ 2 jet events



CDF Run II Preliminary $\int \mathcal{L} = 3.0\ \mathrm{fb}^{-1}$

0-jet evt 0 GeV/c^2

$t\bar{t}$	0.96	±	0.19
DY	64.43	±	14.65
WW	$\boxed{280.42}$	±	38.99
WZ	12.17	±	1.93
ZZ	17.29	±	2.74
W+jets	83.61	±	17.98
$W\gamma$	79.15	±	21.12
Total Background	**538.03**	±	**50.15**
$gg \to H$	8.38	±	1.29
Total Signal	**8.38**	±	**1.29**
Data	**552**		

CDF Run II Preliminary $\int \mathcal{L} = 3.0\ \mathrm{fb}^{-1}$

2+ jet evt $M_H = 160$ GeV/c^2

$t\bar{t}$	$\boxed{70.34}$	±	14.46
DY	27.74	±	6.75
WW	15.68	±	2.47
WZ	3.33	±	0.53
ZZ	1.35	±	0.21
W+jets	8.38	±	2.27
$W\gamma$	1.80	±	0.47
Total Background	**128.62**	±	**16.33**
$gg \to H$	1.52	±	0.26
WH	1.18	±	0.16
ZH	0.59	±	0.08
VBF	0.61	±	0.10
Total Signal	**3.90**	±	**0.33**
Data	**139**		

VH and VBF contribution dominant 60% (~2.4 evts)

CDF Run II Preliminary $\int \mathcal{L} = 3.0\ \mathrm{fb}^{-1}$

1-jet evt $M_H = 160$ GeV/c^2

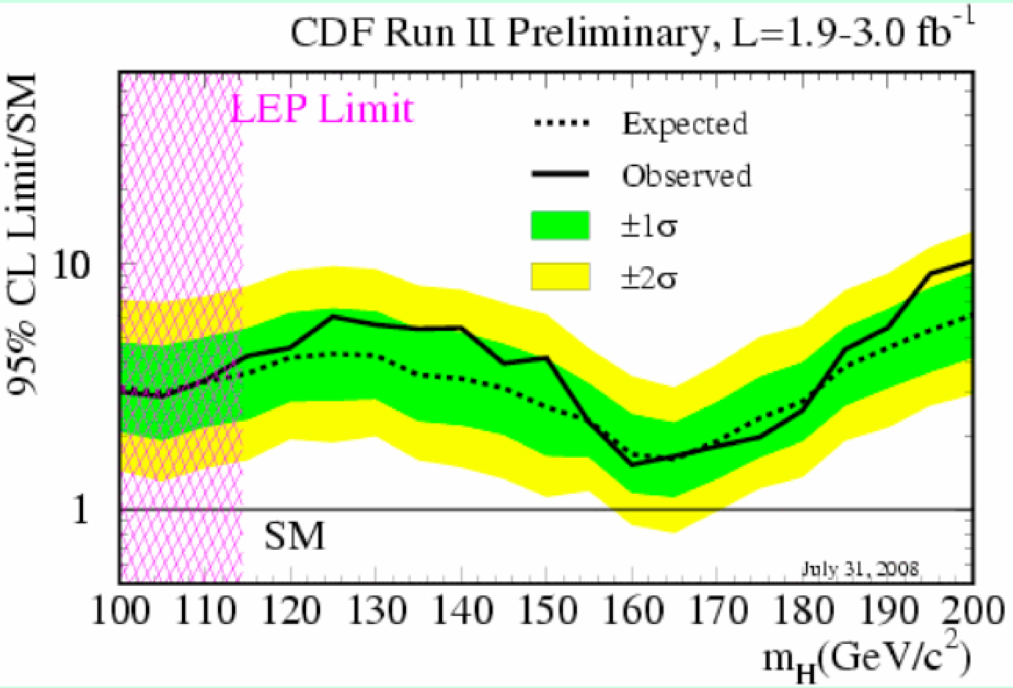
$t\bar{t}$	24.57	±	4.77
DY	42.25	±	9.61
WW	$\boxed{75.10}$	±	10.11
WZ	12.71	±	2.02
ZZ	4.53	±	0.72
W+jets	26.23	±	5.82
$W\gamma$	11.35	±	3.00
Total Background	**196.73**	±	**16.27**
$gg \to H$	4.08	±	0.63
WH	0.57	±	0.08
ZH	0.21	±	0.03
VBF	0.33	±	0.05
Total Signal	**5.18**	±	**0.64**
Data	**227**		

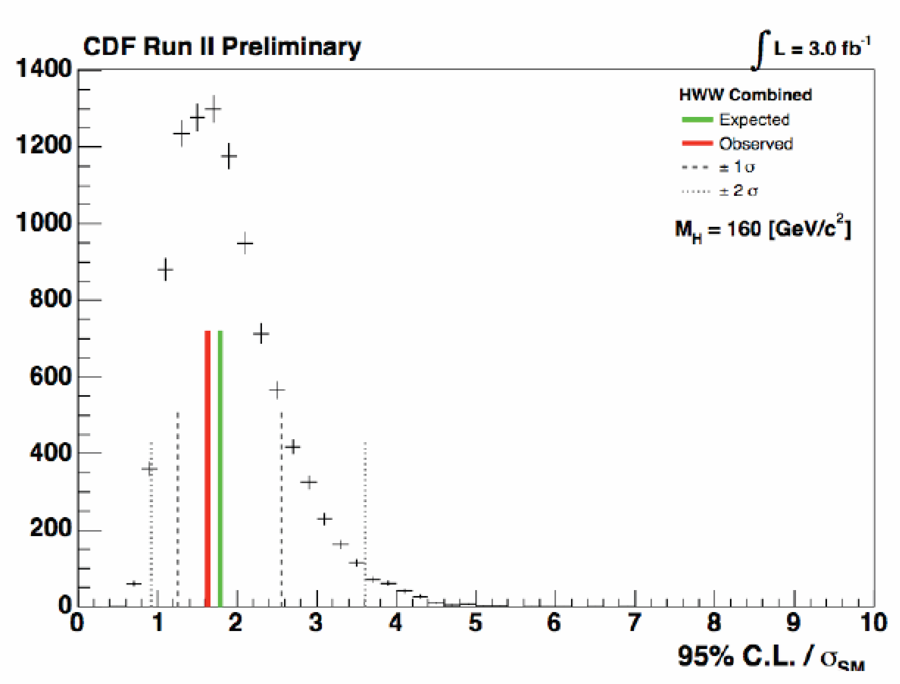
VH and VBF ~1 evt

NN with different inputs are trained for each case
Anti-b tagging is added in the ≥ 2 jets case, in order to get rid of the ttbar background
The results obtained for each of these 3 cases arethen combined,

and the CDF result is

CDF result on 3 fb^{-1} of data

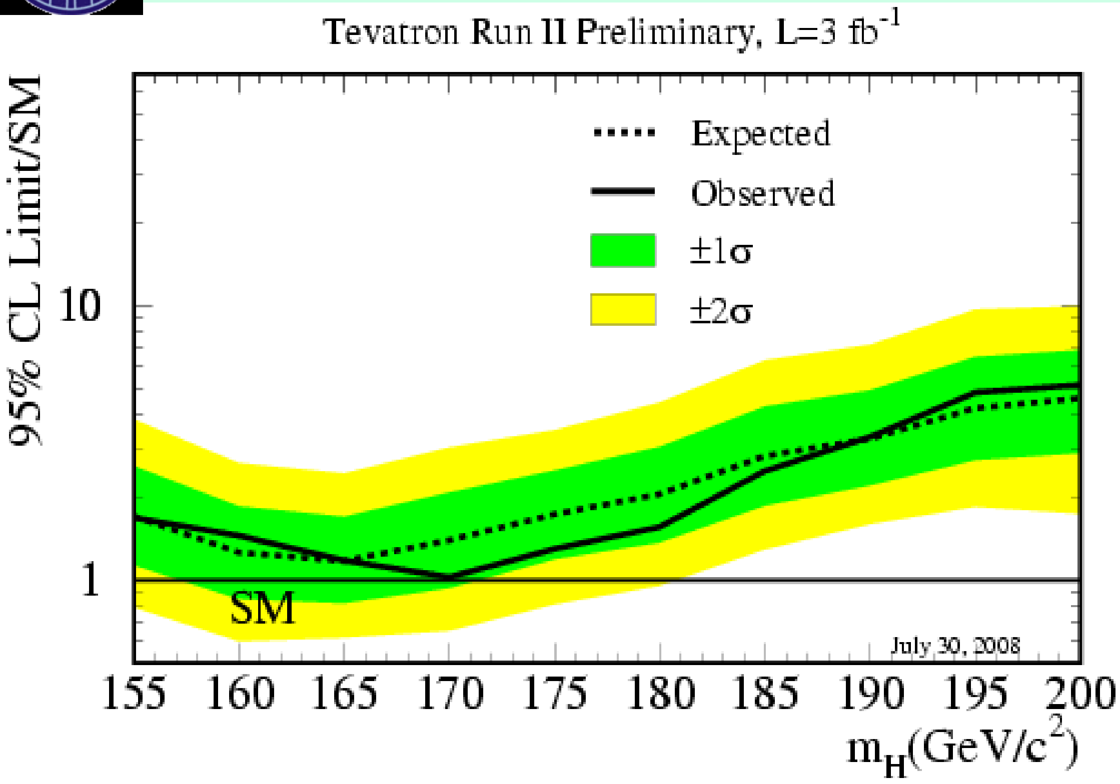




σ x BR (H→WW*) expected limit 1.66 times SM

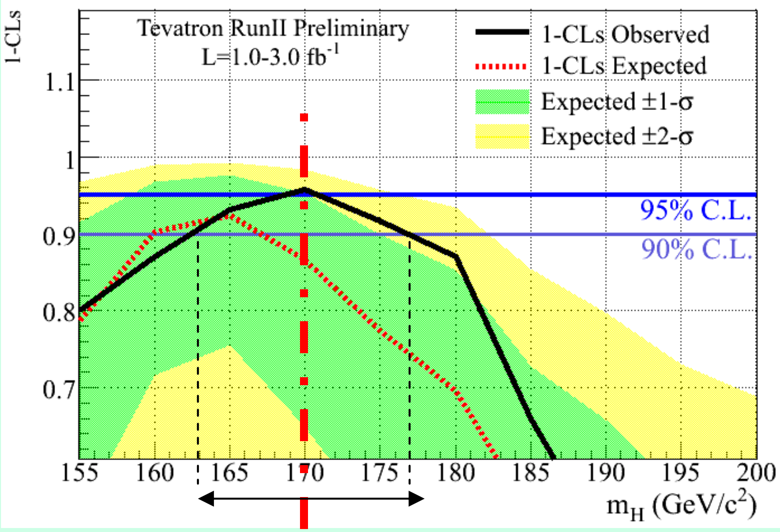
for a Higgs mass of 165 GeV; Observed 1.63

Combining CDF and D0 results *(see next talk)*



Exp. 1.2 @ 165, 1.4 @ 170 GeV
Observed: 1 at 170 GeV

Result verified using 2 independent methods (Bayesian/CLs)

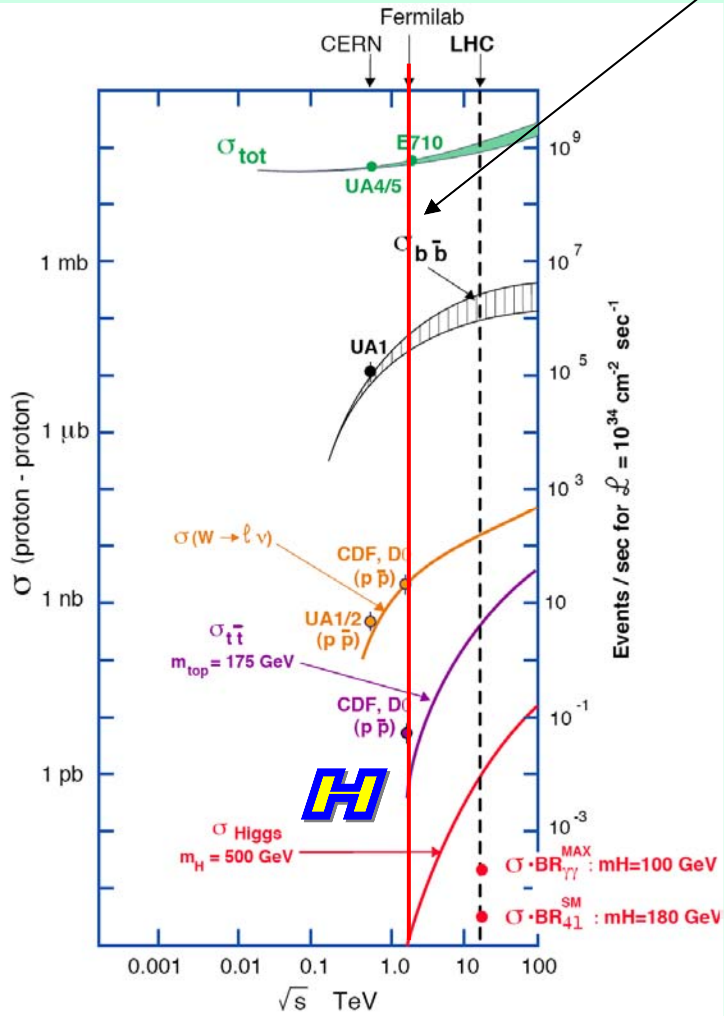


@90% CL ~15 GeV excl. around 170GeV

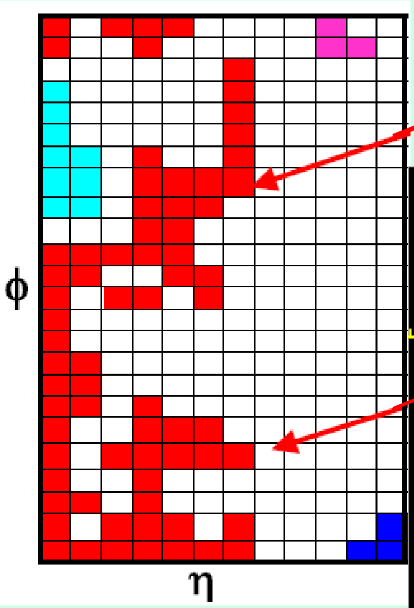
A SM Higgs boson of 170 GeV is excluded at 95%C.L. at the Tevatron

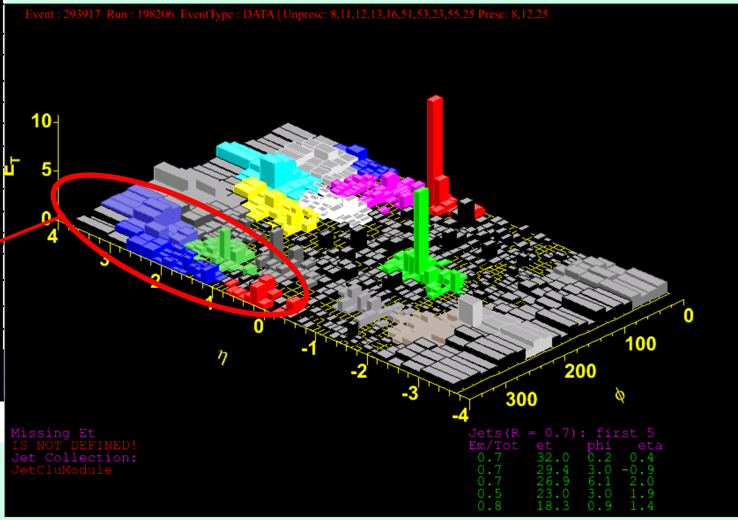
A dedicated new Higgs trigger & N.P. searches

Ten orders of magnitude to fight against!!



High luminosity gives large calorimeter occupancy (pile up) that generates fake clusters/ cluster merging (ex: red towers seen as one single cluster)

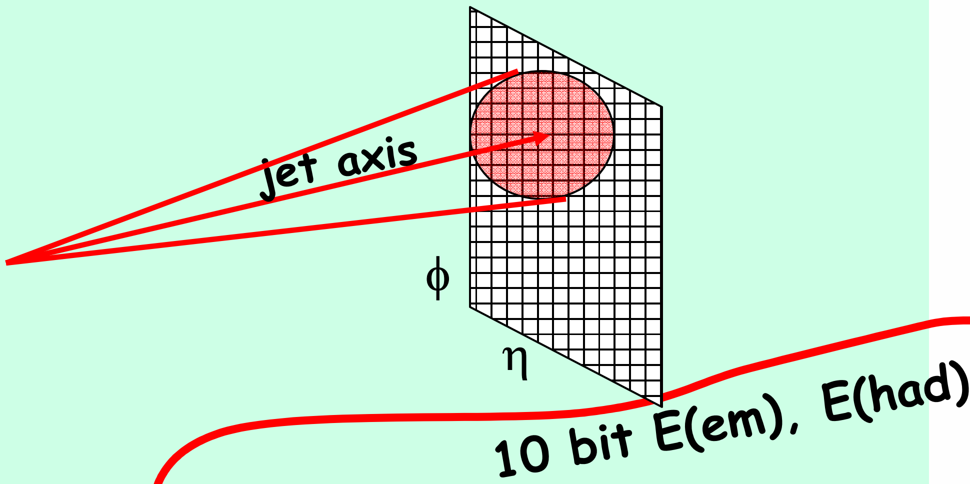


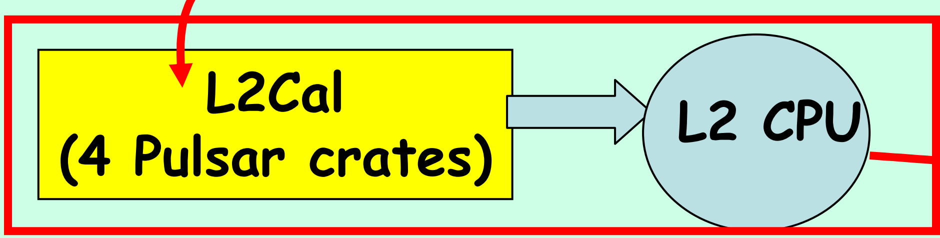


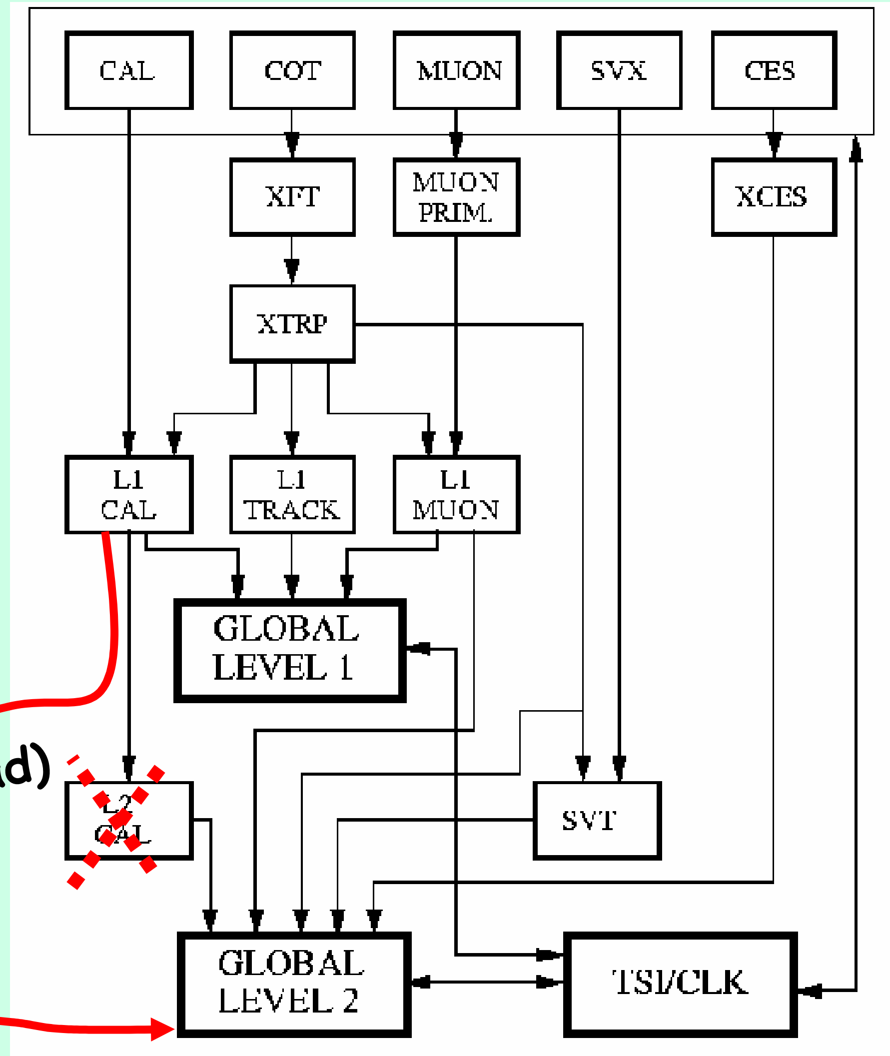
The upgraded Calorimeter Trigger

courtesy of Simone Donati and collaborators

- 24x24 Calorimeter towers E(em), E(had) sent to L2 CPU @ full resolution (10 bit)
- Jet, e/γ clustering, MET computed with offline-style algorithm (immune to pileup).
- **Use fixed cone algo:$\Delta R=\sqrt{(\Delta\phi^2 + \Delta\eta^2)}=0.7$**



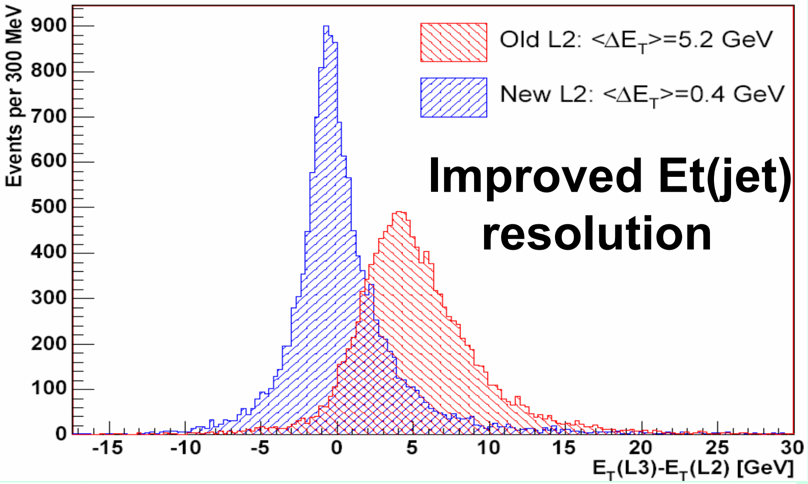


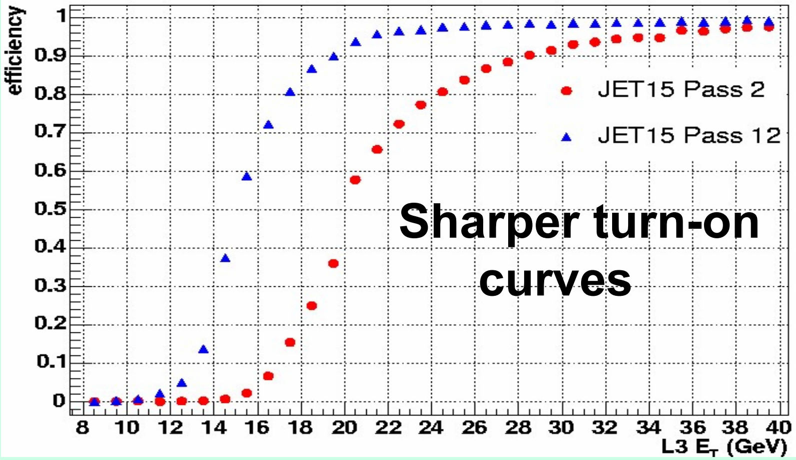


New trigger strategies for the Higgs

The calorimeter trigger upgrade together with XFT-3D, SVT upgrades significantly improves CDF reach for the Higgs (and lots of Physics topics)

Ex: New Jet clustering provides





Mode	Acceptance increase
WH → eνbb	+97 %
WH → μνbb	+110 %
ZH → e+e-bb	+27 %
ZH → μ+μ-bb	+60 %
ZH → ννbb	+30 %
H → lνlν	+24 %

The new data: taken with this upgraded trigger

- **Breaking the waves:**

looking for BSM processes as advertised by our best theoretician friends

Two examples:

=> SUSY in MULTIJETS

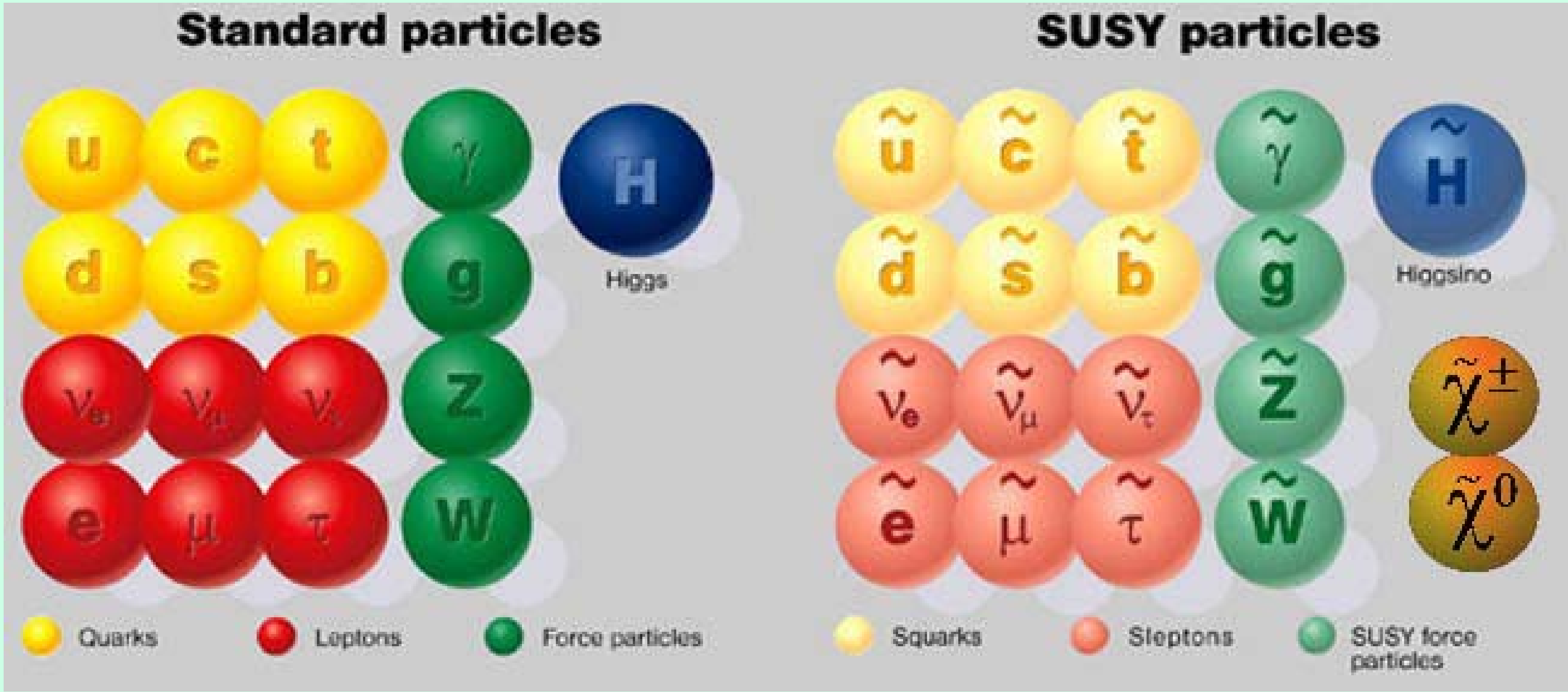
=> SUSY in MULTILEPTONS

Don't forget what we just said on the new trigger update also applies here for the newly taken data!

A minimally supersymmetric world ?

SUSY proposes a new symmetry

Fermions $\longleftrightarrow$ Bosons



Example1: Inclusive search for squark/gluino

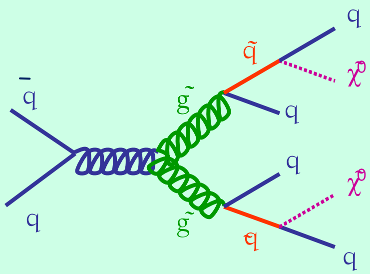
Courtesy Monica D'Onofrio

Final state: energetic jets of hadrons and large unbalanced transverse energy (due to presence of χ^0)

→ **mSUGRA:** Low tan β scenario (=5)

→ Assume 5-flavours degenerate

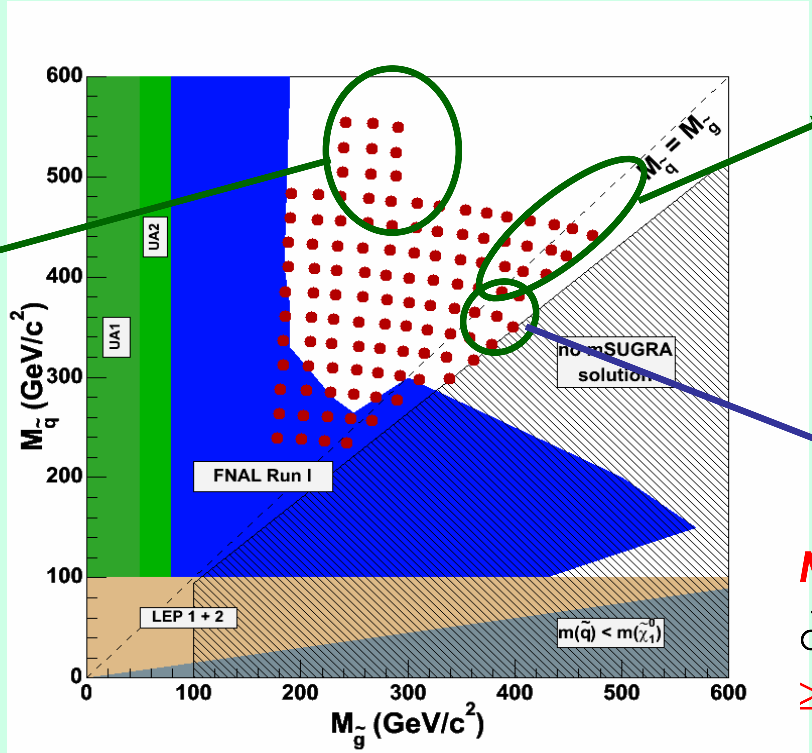
A_0 = 0, μ<0
M_0 $\in$ [0,500 GeV/c^2]
$m_{1/2}$ $\in$ [50,200 GeV/c^2]

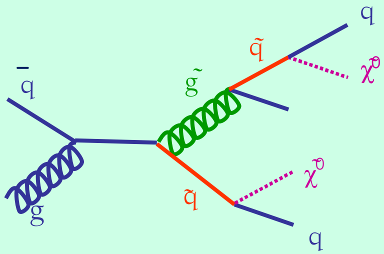


$M_{\tilde{q}} > M_{\tilde{g}}$

$\tilde{g}\tilde{g}$ final state dominates

$\geq$ 4 jets expected

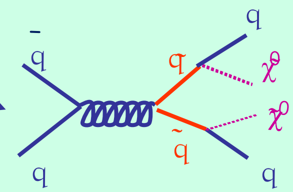




$M_{\tilde{q}} \sim M_{\tilde{g}}$

$\tilde{q}\tilde{g}$ final state dominates

$\geq$ 3 jets expected



$M_{\tilde{q}} < M_{\tilde{g}}$

$\tilde{q}\tilde{q}$ final state dominates

$\geq$ 2 jets expected

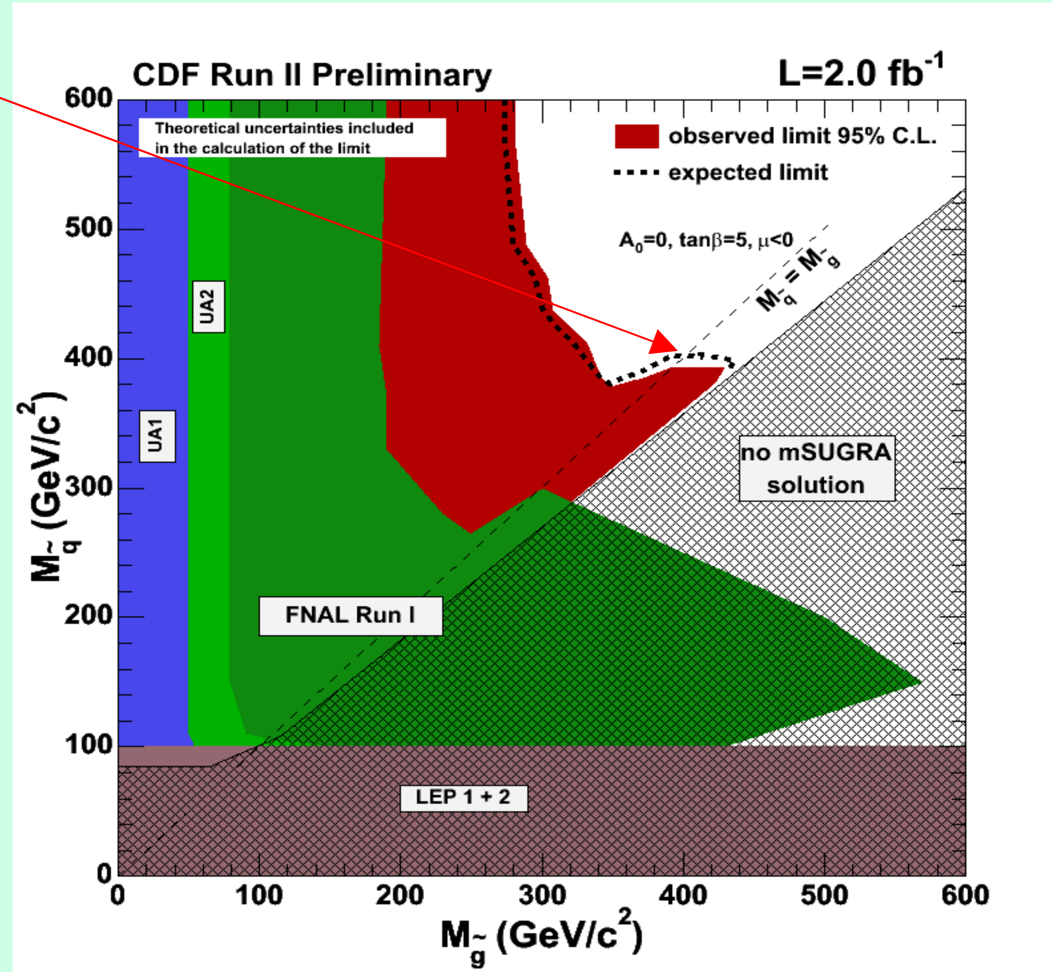
3 different analyses carried out with different jet multiplicities, using missing E_T , $H_T = \Sigma$ ($E_T$jets) and E_T jets

RESULT: 95%CL exclusion limits

If gluino and squark degenerate in Mass: M > 392 GeV/c^2

M(gluino)< 280 GeV/c^2 excluded in any case

Enhanced trigger capabilities will also be instrumental in this search (Etmiss, Jets)

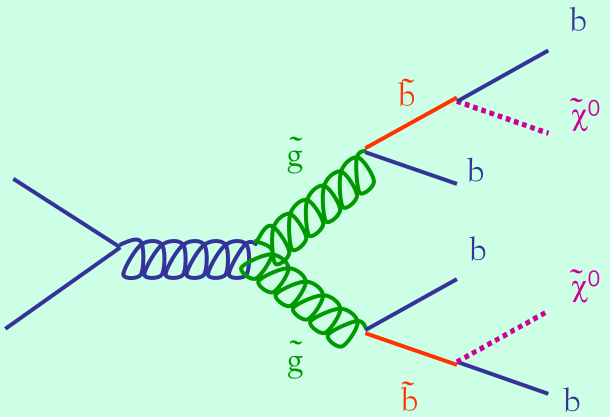


Searches for sbottom quark

- If large tan β, light sbottom is expected
- Dedicated searches for $\tilde{b}$ production (B.R. $(\tilde{b} \to b\, \chi^0) = 100\%$)

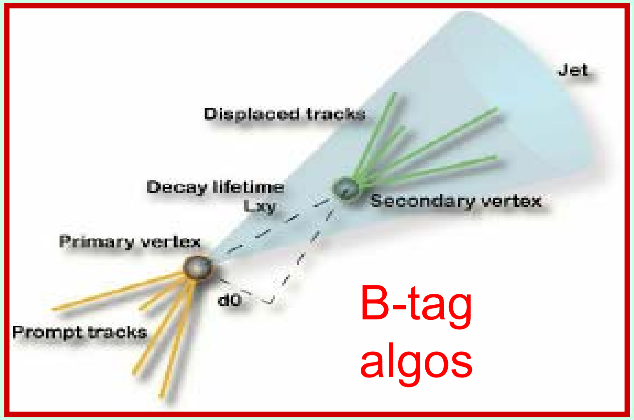
→ direct pair production or **$\tilde{b}$ from gluino decays**

$\sigma_{\tilde{g}\tilde{g}} \sim 10\ \sigma_{\tilde{b}\tilde{b}}$, consider region $m_t, m_{\tilde{\chi}_1^\pm} > m_{\tilde{b}} > m_{\tilde{\chi}^0}$
and mass(gluino) > mass(sbottom)



Final state:

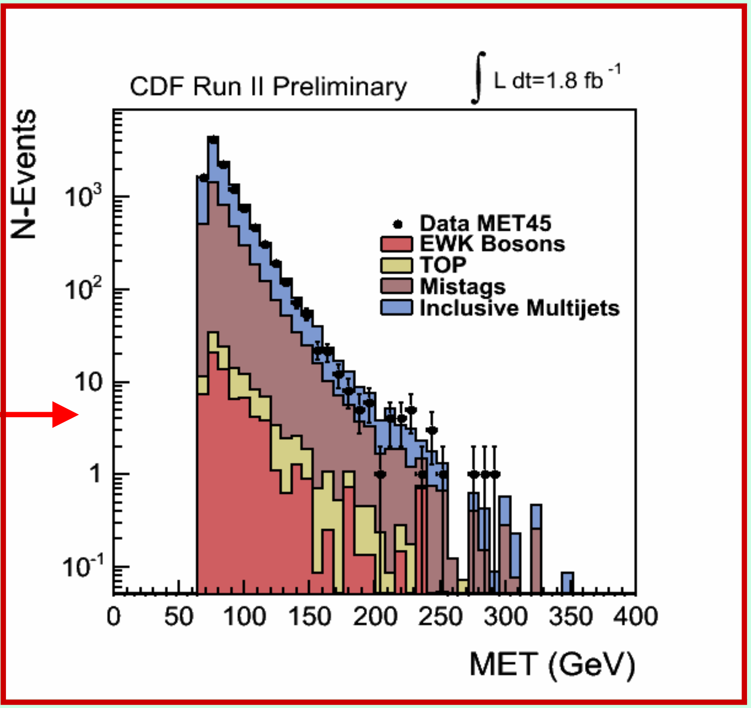
$\not{E}_T$ + 4 b-jets



Main background processes:

- *QCD-multijets*
- light-flavor jets tagging (“mistag”)
- Top production, W/Z+jets, diboson

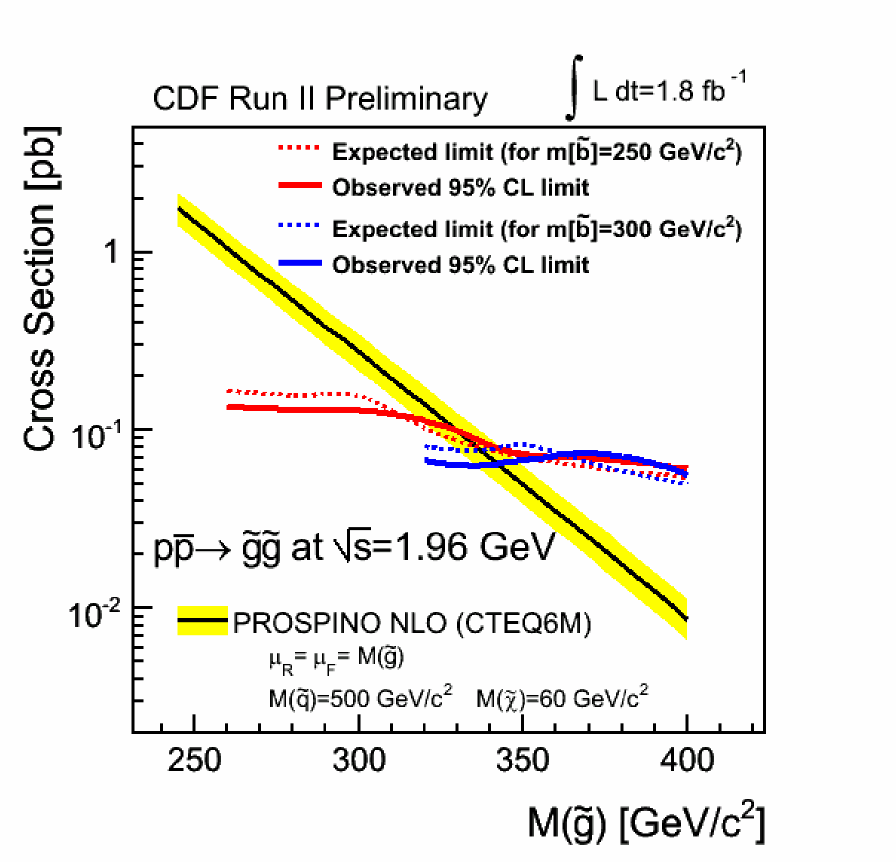
→ Predictions tested in Control Regions

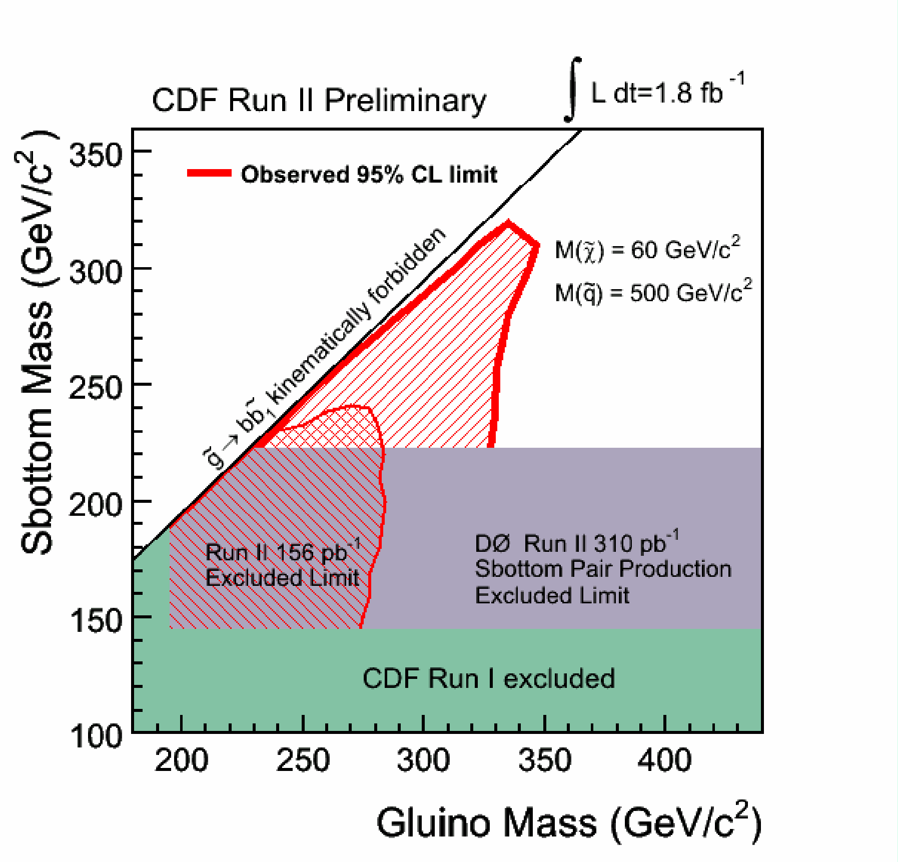


Exclusion limits

Excluded σ above 0.1 pb
($M(\tilde{g})$ ~ 350 GeV/c^2)

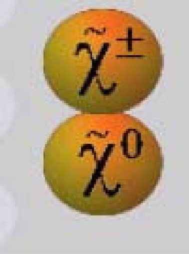
Translated into limits on the gluino-sbottom mass plane





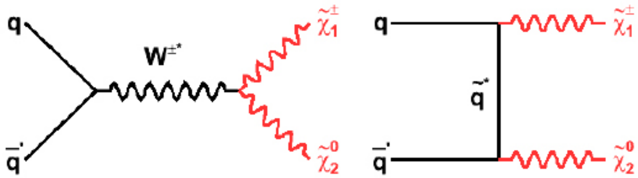
Sbottom masses up to 300 GeV/c^2 are excluded for $M(\tilde{g})$<340 Gev/c^2

Example 2: SUSY Trileptons search

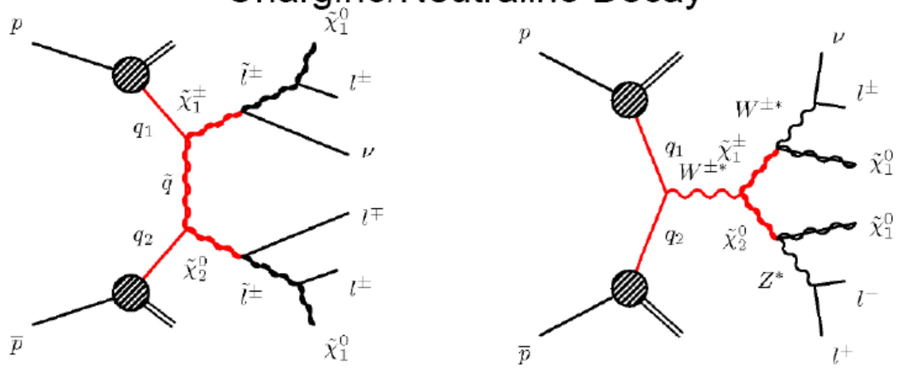


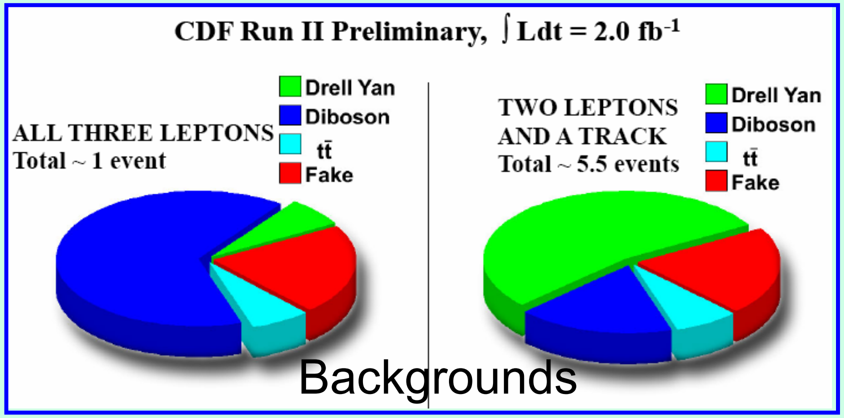
SUSY Force Carriers

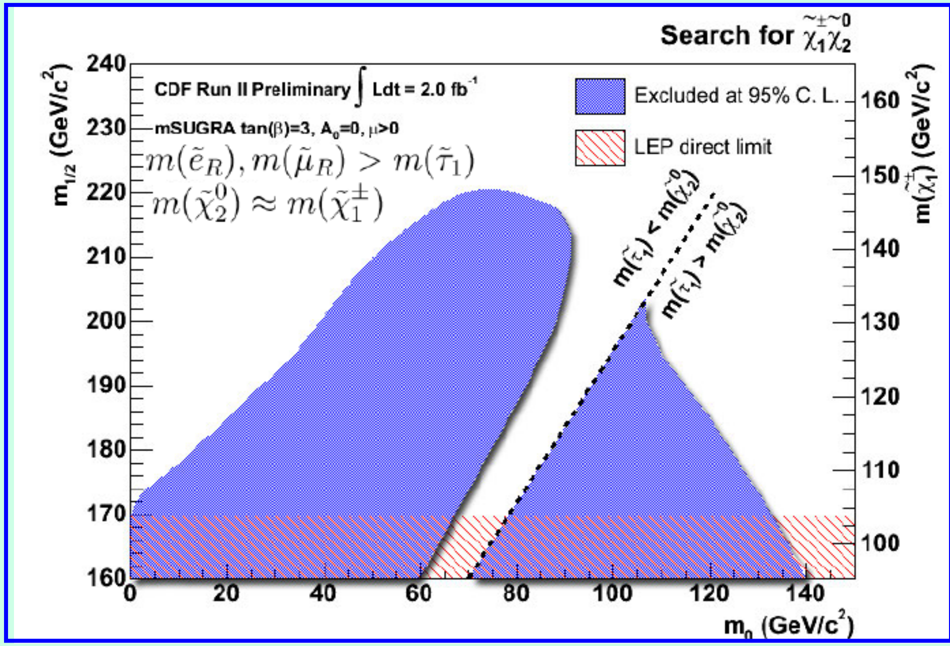
Chargino/Neutralino Production



Chargino/Neutralino Decay



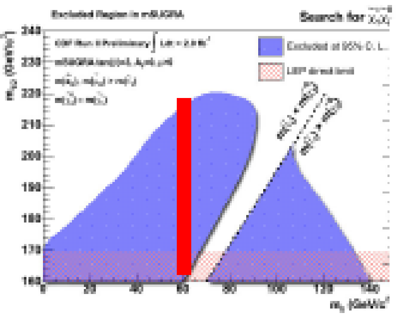


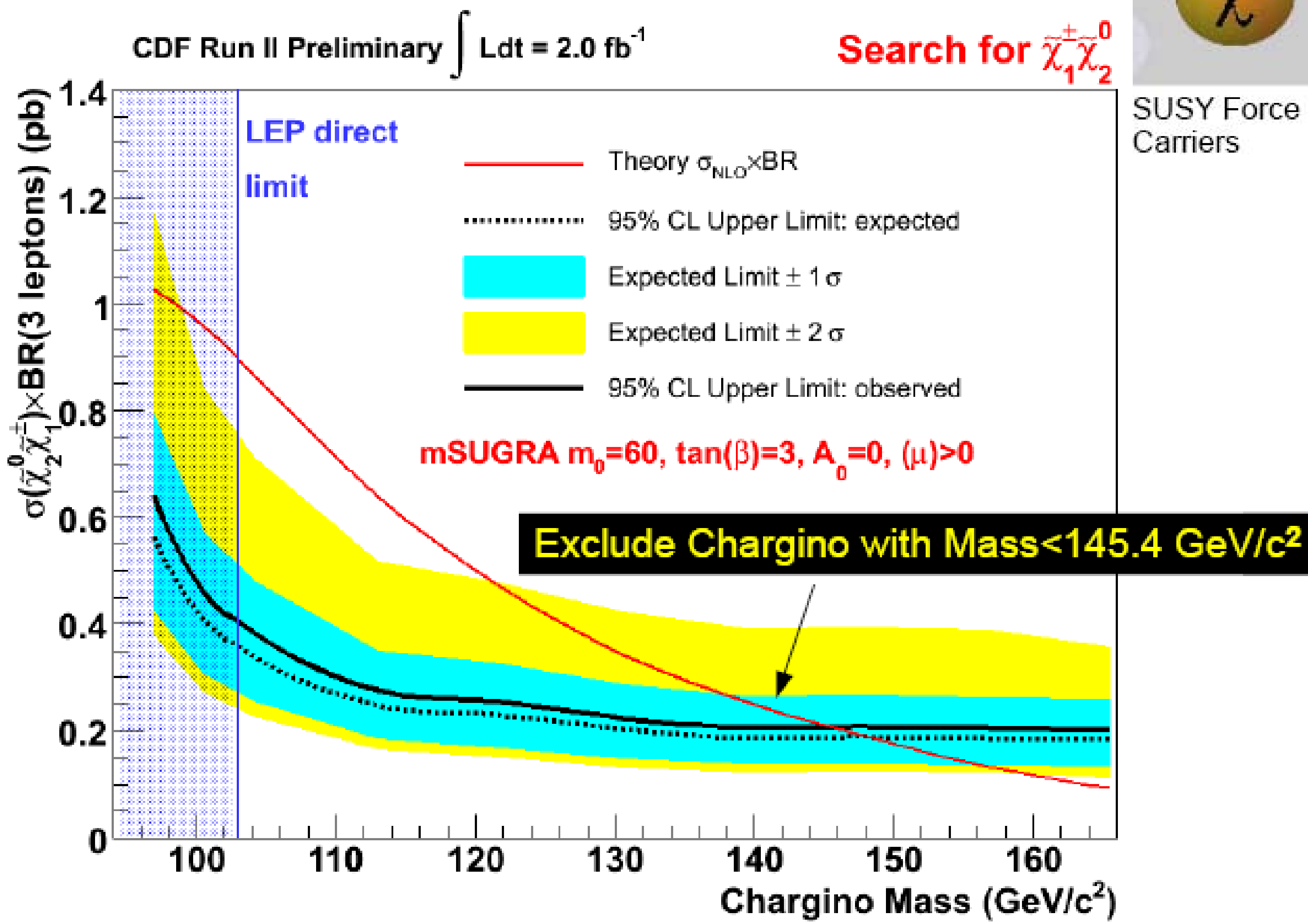


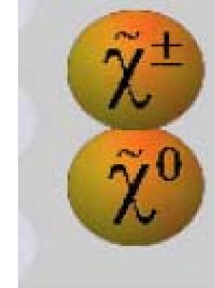
CDF selection:

- Leptons
  - Electrons
    - Tight (gold plated)
    - Loose
  - Muons
    - Tight (gold plated)
    - Loose
  - Tau leptons
    - Tracks

Mass limits for m_0=60 GeV/c^2

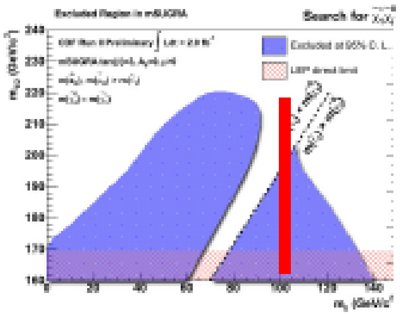


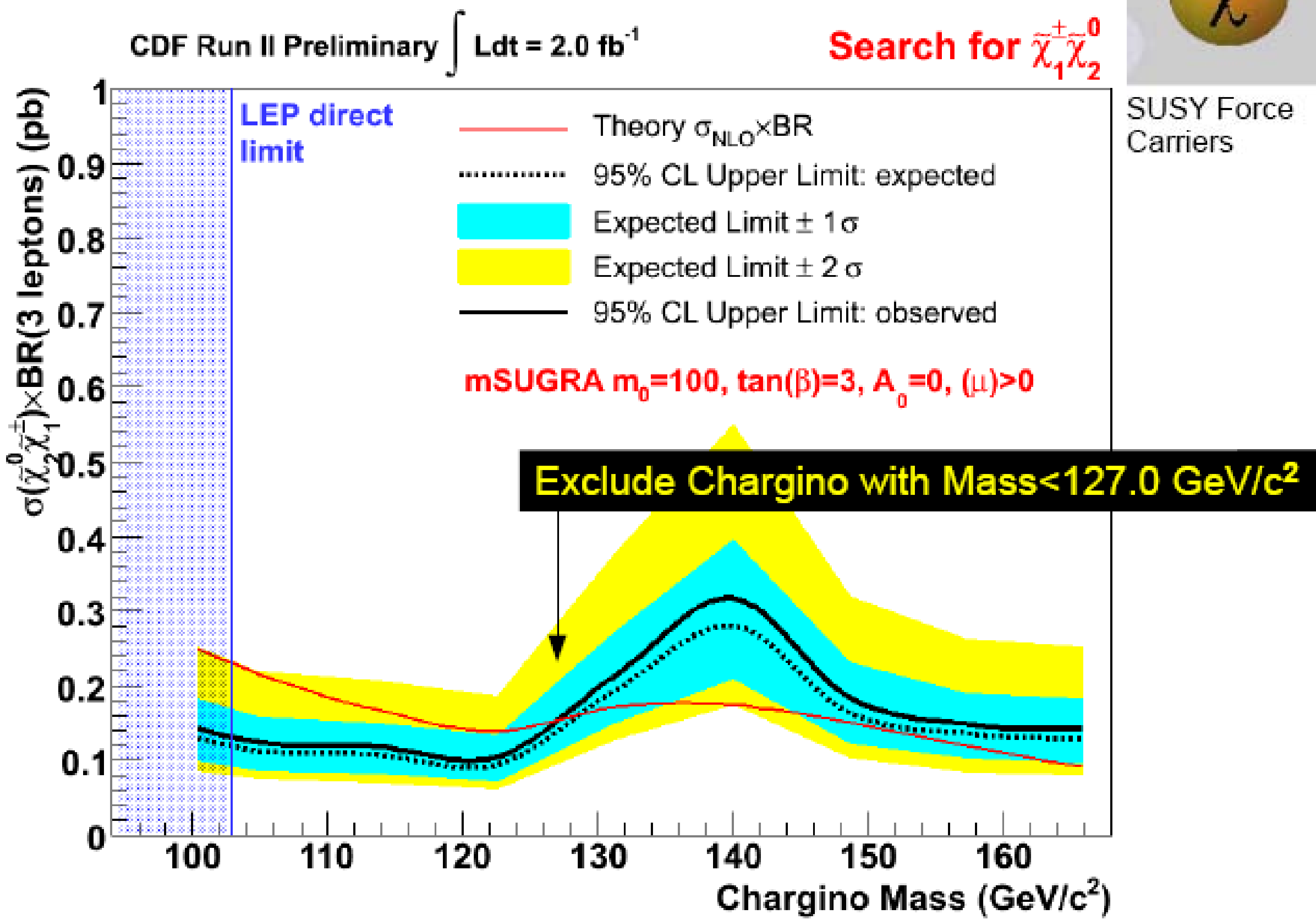


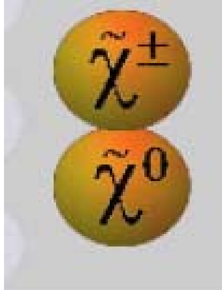

SUSY Force Carriers

Courtesy Sourabh Dube

Mass limits for m_0=100 GeV/c^2



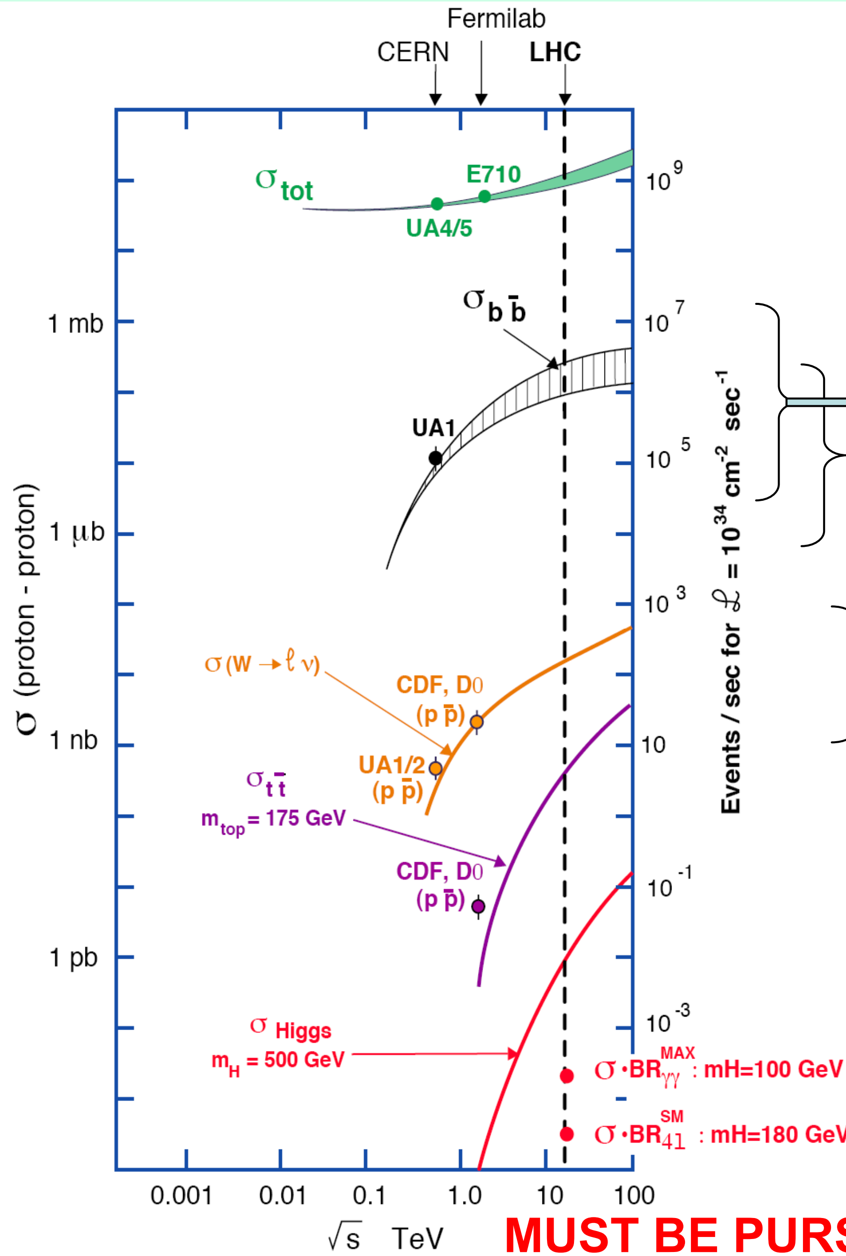




SUSY Force Carriers

Courtesy Sourabh Dube

Since Oct 2001 CDFII:



Improves its Physics reach by making the best of Lum. increase & continuous upgrade of detector performances => WORLD PREMIERES and BEST RESULTS ON:

- QCD: new Jet algo, dσ/dEt, σ(bb),W,Z+jets W,Z+HF, diffractive…
- B,D Phys:CKM, spectro, Lifetimes Mixing, CPV, Asymmetries
- W,Z EWK: W/Z mass , Γ, & other precision measurts (properties)
- TOP: top mass, all decays, σ(tt), single top, prec. measurts (properties)
- Dibosons: all possible SM processes HIGGS: searches on all channels NP searches: a large variety of possible scenarios, incl. theory indept.
- Very rare processes, forbidden & BSM

MUST BE PURSUED with PROPER OVERLAP with LHC

Just do the contrary of what you have been told since you were kids:

VIOLATE the S.M. LAWS.

Look for any deviation from the SM this will be a sign of **B**SM Physics.

But to do so you must be able to perform HIGH PRECISION MEASUREMENTS

THUS better be REALLY SMART

A lot of people must be given credit for their instrumental contributions that lead to these outstanding results:

- credit to the generation of builders of the various CDF phases
- credit to the continuous upgrades even while data taking
- credit to a lot of innovative ideas and
- credit to making them becoming real
- credit to all those who are keeping the detector running all along (especially the crucial pieces: COT, Si, triggers, *etc*)
- credit to the software developers
- credit to the analyzers
- credit to those who are making possible to run such a complex machinery with few people.

CDF is getting now the full benefit of all this with still much more to come

(*) Advertisement to the audience

to be read at the end or after the talk…no time now

This talk tries to give some ideas about the capabilities and present achievements of the CDF experiment to confront the BSM, which is the main goal ahead of us.

The speaker has chosen a few topics and gives a hint on the corresponding Physics goals, analysis framework and CDF detector capability to access the search each one corresponds to.

It is impossible in 40 min to summarize more than 150 published results this last year (58 presented at ICHEP).

The choice is the one of the speaker, the blame for not showing it all or as you would like it , is on her.
The results and more information on all the world class analyses ongoing at CDF and the present results many of them being world's premieres, are in:

http://www-cdf.fnal.gov/physics/S08CDFResults.html

And you are very welcome to contact us for discussing in more details the topic(s) of particular interest to you.

aurore@fnal.gov